MICHIGAN GEOLOGICAL AND BIOLOGICAL SURVEY.

Publication 6
Geological Series 4
Volume 2

Beginning with Chapter V., § 18. For Table of Contents and List of Illustrations see Volume 1.

THE KEWEENAW SERIES OF MICHIGAN

BY

ALFRED C. LANE

PUBLISHED AS A PART OF THE ANNUAL REPORT OF THE BOARD OF GEOLOGICAL AND BIOLOGICAL SURVEY FOR 1909

LANSING, MICHIGAN
...P HALLENBECK CRAWFORD CO., STATE PRINTERS
1911

MICHIGAN GEOLOGICAL AND BIOLOGICAL SURVEY.

Publication 6
Geological Series 4
Volume 2

Beginning with Chapter V., § 18. For Table of Contents and List of Illustrations see Volume 1.

THE KEWEENAW SERIES OF MICHIGAN

BY

ALFRED C. LANE

PUBLISHED AS A PART OF THE ANNUAL REPORT OF THE BOARD OF GEOLOGICAL AND BIOLOGICAL SURVEY FOR 1909

LANSING, MICHIGAN
WYNKOOP HALLENBECK CRAWFORD CO., STATE PRINTERS.
1911

BOARD OF GEOLOGICAL AND BIOLOGICAL SURVEY, 1911.

EX OFFICIO:

THE GOVERNOR OF THE STATE,

HON. CHASE S. OSBORN, *President.*

THE SUPERINTENDENT OF PUBLIC INSTRUCTION,

HON. L. L. WRIGHT, *Secretary.*

THE PRESIDENT OF THE STATE BOARD OF EDUCATION,

HON. D. M. FERRY, JUNIOR.

DIRECTOR,

R. C. ALLEN.

SCIENTIFIC ADVISERS.

Geologists.—Dr. L. L. Hubbard, Houghton; Prof. W. H. Hobbs, Ann Arbor; Prof. W. H. Sherzer, Ypsilanti.

Botanists.—Prof. E. A. Bessey, East Lansing; Prof. F. C. Newcombe, Ann Arbor.

Zoologists.—Prof. W. B. Barrows, East Lansing; Prof. J. Reighard, Ann Arbor; Mr. Bryant Walker, Detroit.

CHAPTER V (CONTINUED).

§18. GLOBE AND CHALLENGE EXPLORATIONS, LIMESTONE MOUNTAIN, PL. XI AND FIGS. 48 AND 59.)

The strike on the Baltic is very much west of south (S. 62° 30′ W.). It continues this course across Section 21 T. 44 R. 34 nearly to the Trimountain line near the center of Section 20. Then it is much shattered and very poor and turns quite abruptly and gradually becomes richer in copper on the Champion property where the strike is S. 26° 27′ W. Next beyond it was tested in Section 1, T. 55 R. 35 on the Globe property (Pl. XI) which was abandoned after a good deal of money had been spent on it. Only a limited section was exposed. The overburden of glacial deposits is heavy along this side of the Range now, from about the Baltic south, as a great moraine[1] extending from Wheal Kate has a course more southerly than the range. The location of the shaft and the three holes to determine the lode on Section 1, T. 55 N. 35 W. is given on Plate XI. Hole No. 2 is farthest north, then comes No. 1 (about 600 A. L. S.) and No. 3. At 280 feet the bed rock a "red trap" was found; at 306 to 585 feet was amygdaloid. See also discussion of samples of water from it. The surface sands proved exceedingly difficult to sink through.

It is about four miles farther to the Challenge where has been a very thorough bit of exploration with enough copper to be tantalizing, by the St. Mary's Company (R. R. Seeber, Supt.) guided by Dr. L. L. Hubbard, their General Manager.

It covers all the Bohemia Range group exposed,—from 655 feet above Conglomerate 8 down. The details of the drill records with large assistance from Hubbard's notes are as follows. See also the discussion of the distribution of salt water and especially Fig. 59 accompanying the same.

---

[1]For further details, see F. Leverett in Publication 7, and § 19.

St. Mary's Mineral Land Co. Challenge drill hole 7. T. 52 N., R. 35 W. Elevation above datum 208.5 (1110 A. T.), above Portage Lake 717 ft., above cross-cut about 842. 1360 feet north, and 1016 feet west of the quarter-post between Sections 21 and 22. Inclined at an angle of 57° to E. 38° S., so that if the dip is 61.5° the depths along the hole correspond to breadth of outcrop. At a strike of N. 45° E. to N. 38° E. there would be (comparing it with d 6) (1360-400) sin 45°+ (1016-80) cos 45°=1332 feet to 1305 feet difference in a section across the strike, which at a dip of 59.5° would mean about (1150) feet.

This would make the top of 6 correspond to about 1110 feet in No. 7. Now we have in No. 7 conglomerates—

(5) 1254-1259
(40) 1302-1342
(27) 1379-1406

The question is, do they correspond with
57-83 in No. 6.
or 226-259
or 368-397?

The most probable correlation is of d 7. 1302-1406 with d 6. 57-83. To suppose no correlation is to suppose something unnecessary and a dip steeper than there are any other indications of. To suppose a correlation of 7. 1406 with the next lower conglomerate 6, not only makes an ultra flat dip, but the beds above and below match poorly. This correlation (7. 1322 to 1323+37′ for difference in altitude with 6.0) means a dip of about 61.5°. An allowance of perhaps 1% might be made for the fact that the hole is not at right angles to the strike.

1.	Surface	32	(29)	
2.	Trap d 7. 92-124			
3.	d 7. 124-145	21	(19)	
4.	d 7. 145-160	15	(14)	
	At 152-155 epidote.			
5.	Ophite	232	(210)	
	Amygdaloid d 7. 160-162			
	Trap d 7. -394			
	Alteration seam, fine grained ? at 171			
	Coarse, ophitic at 173			
	Altered at 209			
	Cf. hanging of Winona lode			272
6.	Amygdaloidal melaphyre d 7. 394-402½	8½	(8)	
7.	Amygdaloid d 7. 402½-406½	8½	(8)	
	Trap d 7. 406½-411			
8.		6	(5)	
	Amygdaloid d 7. 411-414			
	Trap d 7. 414-417			
9.	Top of flow or thin flows of	26	(23)	
	Amygdaloidal melaphyre d 7. 411-437			
10.	Ophite d 7. 437-563=126			
	Amygdaloid above?			
	Trap to d 7. 563			
	Inclusions at d 7. 513			
11.		21	(19)	
	Amygdaloid d 7. 563-566 with large calcite			
	Blotches d 7. -573½			
	Trap d 7. 573½-584			

12. 11 (10)
Amygdaloid d 7. 584-590
Calcareous and highly epidotic, compare Winona lode.
Trap d 7. 590-595

13. Amygdaloidal melaphyre 15 (14)
Amygdaloid d 7. 595-599
Trap d 7. 599-610

14. 6 (5½)
Amygdaloid d 7. 610-612½
Trap d 7. 612½-616

15. 14 (13)
Amygdaloid d 7. 616-620
Amygdaloidal trap d 7. 620-622
Trap d 7. 622-630

16. 41 (37)
Amygdaloid d 7. 630-633
Amygdaloidal melaphyre d 7. 633-640
Trap d 7. 640-671

17. Amygdaloidal melaphyre 23 (21)
Amygdaloid d 7. 671-679
Trap d 7. 679-694
Amygdaloid streak at d 7. 680-682

18. 122 (111)
Amygdaloid d 7. 694-697
Red, altered.
Trap d 7. 697 to 700-816
At 712 and 720 feet veins of calcite parallel to core and at 794 to 795 feet a vein of calcite with copper.
Base below "hanging" of Winona Lode (383)

19. *Conglomerate* d 8. 816-869 53 (48) 431

Pebbly, with basic matrix and copper 816-836, then to 851 amygdaloid?, perhaps a flow; then to 853 sandstone; then to 856 laminated, shaly sandstone; then to 869 amygdaloid conglomerate. This is the first conglomerate in nearly 800′ anyway. In the next 850 (1379-869+397-57) feet there are a goodly number. It is presumably Marvine's Conglomerate No. 8.
Cf. Wyandotte Hole 8. 186-200

20. 60 (55)
Chloritic amygdaloid d 7. 869-871½
Occasional amygdules to 881
Trap? d 7. 871½-929

21. 129
Amygdaloid d 7. 929-948
Trap d 7. 948-1058
Down to here from notes of L. L. H.

22. Ophite 196
Amygdaloid d 7. 1058-1083
Trap d 7. 1083-1254
Grain at
1231, 1244, 1249 feet
2, 1, ½ mm. augite mottles respectively.

23. Conglomerate d 7. 1254-1263 9 (8)
Sandstone at 1259
Marvine's No. 7 or 7½
24. Amygdaloidal melaphyre d 7. 1263-1278
Coarsest, but a fine grained trap at 1270
25. Melaphyre
Amygdaloid d 7. 1278-1287
Very amygdaloidal at 1278
Trap d 7. 1287-1302
Fine grained.
26. Conglomerate d 7. 1302-1406 (104)
A little basic matter but mainly felsitic to 1388, sandstone to 1393, with a little conglomerate to 1395, amygdaloidal to 1398, then largely sandstone. This may well be Marvine's No. 7. The sandstone base seems to be struck at the top of hole 6.
Base of No. 19 to base of No. 26, 1406-869=537 (488)
27. Doleritic, feldspathic melaphyre
Amygdaloid d 7. 1406-1441+
Coarse, feldspathic, with scattered white amygdules, corresponding closely to Hole 6, Belt 3, 83 to 129.

Challenge drill hole 6. T. 52 N., R. 35 W. Elevation above datum 239 (road bridge over 13-mile creek = 100) above long cross-cut about 862 (Fig. 59). 2800′ west, 2160′ south of the ¼ post between sections 15 and 22, and 80′ west and 400′ north of the ¼ post between Sections 21 and 22. Nos. 6 and 7 are ½ mile away from 2 and 3 and upon the plateau. The inclination of the hole is 57° and the dip of the strata in the hole seems to be about 59½° (63½°) from the drill hole, so that the thickness along the hole should be multiplied by .89 for true thickness. In the first 400′ there are at least 3 conglomerates, which may correspond to some of the 3 conglomerates in No. 7 at the bottom 836 to 1342. Then comes a bunch of heavy ophites with mottles up to 4 mm.

1. Surface d 6. 0-57
2. Conglomerate 26 d 6. 57-83. Marvine's No. 7 perhaps. (24)
55-67 pebbles, felsitic, red, with small phenocrysts, also porphyrite.
67-72 more matrix, pebbles of amygdaloid, etc.
72-79 mainly sandstone, slope of dip against core 8 to 3 to 4.5 or 4.
79-83 finer, more red shale, slope of dip very uniform 78:38
3. Feldspathic melaphyre 46 (41)
Amygdaloid d 6. 83-90
Well-marked d 6. 83-86, white amygdules, then chloritic and feldspathic.
Trap d 6. 90-129
Feldspathic, with occasionally chloritic amygdules, feldspathic, with copper at 99, getting compact from 110 down, with occasional speckled doleritic bunches.
4. Amygdaloidal melaphyre 10 (9)
Amygdaloid d 6. 129-139
Trap with sediment, a fine black, also brecciated with green am.; hard with white amygdules to 135; yellow-green epidote to 139; a gush of the underlying?

5. Feldspathic melaphyre 38 (33)
Amygdaloid d 6. 139-150
To 150 a typical hard amygdaloid with white amygdules on dark purple ground; near 150 a very feldspathic green seam.
Trap d 6. 150-177
To 167 coarser, feldspathic; at 163 coarse; at 167 the feldspar is 1 to 2 mm.; coarsest about 170; to 172 feet epidote, yellow-green.

6. Melaphyre (separate flows?) d 6. 177-226 (43)
Yellow, fine grained epidote at 177; apparently coarser at 193; at 194 calcite seams nearly parallel to core, making 12° to 11° with it; at 199 clasolitic with apparent contact at angle of 60° to core as usual; at 201′ 9″ fine grained, and thence to 204; calcite seams at 18° to the core length; at 204 to 213 slightly feldspathic and coarse. Amygdaloid with a clasolitic seam at 213 feet; at 214-224 the same calcite seams probably nearly perpendicular to the bedding at an angle of 14° to 15° with core barrel. There are other transverse seams at 224 quite amygdaloidal.

7. Conglomerate, Marvine's No. 6? d 6. 226-259 (29)
Well-marked, round pebbles, both of felsite and amygdaloid. Cross-bedding lines at 40° with core.
There are a large number of basic pebbles.
d 6. 241-252 half-inch black and red pebbles
d 6. 254-256 sandstone slope 63° against core
d 6. 257-259 " finer, calcite lines (160)

Slopes 58°, 63°, 65° very well marked, cross-bedding is near 54° (37)
Base from base of Marvine; 7. (6.83) (147 to 160)
" " " 8. (7.869) (648)

8. Ophite 42
Amygdaloid d 6. 259-301
d 6. 259-263 small amygdaloidal slope; at 250 small amygdule line distinctly 58° against core.
Trap d 6. 269-301
Calcite seams and few amygdules at d 6. 275-282 fine grained, at 282-3 calcite seams at 45°, fine grained ophitic mottling 287-290, a little coarser at 294. Apparent contact at 296 feet, but not very amygdaloid; 294-301 is chloritic ophite.

9. Amygdaloidal melaphyre 22 (20)
Amygdaloid d 6. 301-305
Marked white on red ground to 303, then yellow-green epidote to 305.
Trap d 6. 305-323
Then more compact to 315 and finer to 323, where there is a well-marked contact at 63.5° to core.

10. Amygdaloidal melaphyre 21 (19)
Amygdaloid d 6. 323-339
With epidote streaks 330-334; and a spotted banding parallel to dip at 63.5° to core 334 to 337, largely epidote to 339.
Amygdaloidal trap d 6. 339-344
Fine grained feldspathic, largely amygdaloid

11. Scoriaceous conglomerate at 344 0 (0)
Narrow streak on top of 12?, but cf. 13

12. Amygdaloidal melaphyre d 6. 344-365=21 (19)
Amygdaloid d 6. 344-351

345-347 often epidotic
amygdaloid 351-359
The rest above and below the contact at 365 feet is nearly all changed to epidote

13. Sandstone and basic conglomerate d 6. 368-397=29 (26)
Upper contact has usual slope about 63.5° against core.
365-368 epidotic, to 372 indurated, 372-380 same passing down into basic sandstone
d 6. 388-389 basic sandstone and scoriaceous conglomerate.
If 15 correspond to the doleritic ophite of the cross-cut, then 13 to 11 would pretty well match lodes C and D in the cross-cut and Hole 2, Belt 7. But in the cross-cut there are 340 feet above C and D without conglomerate, see Figure 59.

14. Ophite (72)
Amygdaloid d 6. 397-413. Cf. lode C.
d 6. 400-408 epidotic; 408-413 fine grained with calcite seams slope against core 51.5°.
Trap d 6. 413-480
Grain at: 414, 417–424, 428–431, 435, 438, 445–450, 458,
2, 2–3, 3, 4, 3–4, 4–5, 3–4,
465, 476, 476?, 480 feet respectively augite mottles
3, 2, 1, contact

15. Ophite 102 (91)
Amygdaloid with copper d 6. 480-499. Cf. lode B.
Brecciated to 485; epidotic to 494, trap and epidote at 495, and ophitic at 497, seamed at 498, epidote and copper at 499.
Trap d 6. 499-582
Grain at: 505.6, 511–512, 515, 517 & 526, 534–548,
1, 2, 2–3, 3, 3–4,
553 to 559 finer, 562, 569, 575, 576, 582.
3, 2–3, 1–2, 1, 0.5, ?

16. Ophite, doleritic 154 (136)
Amygdaloid d 6. 582-595. Cf. lode 1 or A. St. Mary's No. 2, 228-294. Such a correlation implies that the throw along the fissure is of the northwest side down, or that there is some cross-fissure.
To 592 very amygdaloid, fine, epidotic; to 595 small chlorite amygdules.
Trap d 6. 595-736
At d 6. 599-601 amygdaloid streak near flow ? with fine chloritic amygdules
d 6. 601-608 long cores, fine grained with small amygdules; at 612 a white seam parallel to bedding 67° against core, with copper; at 619 altered, with copper, fairly coarse, 2 mm. mottles.
Grain at: 619–623, 640, 725, 730 feet respectively augite
mottles 2–3, 3–4, 1, 0.5 mm. diameter.
At d 6. 634 very epidotic with copper.
At d 6. 625, 627, 630 doleritic, altered, epidotic.
Cf. the doleritic ophite between 1 and 2 in the cross-cut.

17. Amygdaloidal or scoriaceous conglomerate
Cf. lode 2; St. Mary's d 3. 905 to 925 d 2. 549-590
d 6. 736 - 769=33 (30)
d 6. 736-740 appears like a red and white amygdaloid, then passes into an agglomerate with fragments not rounded and of the same general

nature; at 754 the fragments are large and full of bubbles; then it becomes more epidotic, but though the general structure is more uniform, outlines of fragments appear. These gradually fade, but the epidotic alteration obscures the contact with the underlying trap.

18. Ophite (eroded) 104+

Amygdaloid (eroded?)

Trap d 6. 769-885

Grain fine to 779, at	785–700,	794–800,	810,	825,	840,	
	1–2,	2–3,	3,	3–4,	coarsest,	

847,	863,	883–885	
3–4 finer,	3,	1–2	mm. across

Cf. trap between lode 2 and lode 3

19. Basic sandstone and amygdaloid conglomerate d 6. 892-950 (52)

To 896 sandstone (slope against core 8:3), dip 54° with calcite seams parallel to it; to 914 a uniform basic sandstone dip 59.5° with white, perhaps vertical calcite seams to 945 amygdaloid fragments with a red mud or sand matrix, the bottom uncertain, the transition to an ophite with no distinct amygdaloid on top gradual exactly like No. 17.

Cf. lode 2 bis. Nos. 17 and 19 are evidently closely allied.

Cf. St. M. 3. 910-925

20. Ophite 24 (21)

Trap d 6. 950-974

Grain at:	956,	959,	970,	974 respectively augite mottles very
	minute,	1–2,	very fine grained contact.	

21. Ophite 68 (61+20)

Amygdaloid d 6. 974-992

Clasolitic and black, then fine grained, brown, then coarse, and finally epidotic amygdaloid.

Cf. St. M. 6. 1012 to 1030, lode 3 of figure 59.

Trap d 6. 992-1042 (+20?)

Grain at:	1000,	1013,	1021,	1042 feet respectively
augite mottles	2,	2,	2–3,	2 mm. across

20 and 21 appear to parallel the traps of lodes 3 to 5.

But if such is the case either the strike is northeast, like the big fissure, or there is a cross-fault.

Challenge drill hole 3. Elevation above Lake Superior 575. 488 feet west, 400 feet south of the quarter post between Sections 15 and 22. Drilled at an incline of 59° at right angles to the supposed strike of the formation which was at first taken as N. 38° W., as an average between that of the Champion and that near Elm River. The developments show that N. E. might be nearer but the cos (47°-38°) is so near to 1 that it may be neglected in considering the running record of the hole. The distance between 2 and 3 at right angles to the strike is=678 to 585 feet.

Thus No. 3 should be something less than that above No. 2, and at the bottom No. 3 seems to strike the same horizon about 500 feet deeper than No. 2 and the well-marked conglomerate at 500 feet in No. 3 does not appear in No. 2.

Surface? d 3. 0-172 (172)

5′ Loose rock

4 " "

2

	3′ 6″ sand and trap, ran in	d 3.	172-181	(9)?
	2′ sand and trap	d 3.	181-189	(8)
1.	2 Conglomerate?		-191	
	Cf. No. 6 at 259 feet.			
2.	Trap 3′ 2″	d 3.	191-194	
	about ⅔ to ¾ sand			
3.		d 3.	-228	
	Amygdaloid trap		-237	
4.	Trap		-300	
	Amygdaloid		-306	
5.	Am. and trap		-326	
	Amygdaloid		-334	
	Amygdaloid and trap		-344	
	Fine trap		-364	
	Trap		-368	
6.	Ophite			
	Amygdaloid and trap Lode E.		-374	
	Trap		-386	
	Trap		-461	

Cf. No. 6 at 368 feet. Grain of trap at 364 2 mm., at 368 feet seam and at 390 calcite seam, at 379 3 mm., at 396 finer than at 408, at 402 to 408 4 mm., at 417 3-4 mm. and 435 2 mm; 411 1 mm; 455½ ½mm.

7. Conglomerate 461-500 (25)

Fine grained basic sandstone (called trap by drillers) 462 to 476, slope against core 12.5° which would imply a dip of 43.5°+ the amount the hole has flattened; felsitic rounded pebble conglomerate at 479; amygdaloid conglomerate at 500. Struck in No. 3 east cross-cut at 570′, (or is that the conglomerate at 191 feet and this "lode 2"?)

8. Brecciated ophite (39)

Amygdaloid d 3. 500-503

At 504 seam red, and at 513 and 538 ft. mottled 1-2 and 1 mm.

Trap d 3. 503-544

9. Ophite 94 (81)

Amygdaloid 14 d 3. 544-558

Broken with large blotches of calcite d 3. 544-546

Trap 80 d 3. 558-638

At d 3. 558-563 epidotic, at 563 fine, at 568 1 mm., at 573 2 mm. mottles, at 583 finer than 593, at 593 2 to 3 mm. mottles and at the same time amygdaloid inclusions indicating a dip of 45° to 46°; at 606 3 mm., at 614 to 625 1 to 2 mm.

At 558 to 563 very epidotic trap.

Cf. top trap of No. 2 to 228 feet.

10. Ophite 164 (142) (153) in second level.

Amygdaloid d 3. 638-672

Red and white typical brecciated. Lode at 390 to 415 in cross-cut.

With calcite blotches and at 672 copper, ending with 4 or 5 feet of semi-amygdaloid and clasolitic matter.

Trap d 3. 672-812

Mottles are:

at 675;	690;	704–713;	727;	753;	756–766;	772;	785;	793;
1;	2;	2 to 3;	3;	4 to 5;	4;	3 to 4;	3;	2;

796; 808 feet
1 to 2; 1 mm.
From 687-690 is epidotic; at 713 is a seam.

11. Amygdaloid and amygdaloid conglomerate. Lode 2. 31 (27)
Amygdaloid with small blotches of calcite—foot of trap? d 3. 812-822
Amygdaloid conglomerate d 3. 822-843
Light colored cement last 5 feet.

12. Ophite (57)
Amygdaloid d 3. 843-847
Coarse and brecciated, probably eroded.
Trap d 3. 847-905
Grain is:
at 848; 851; 853-859; 859-866; 866-875; 879; 880-890;
½; 1; 1-2; epidotic; 2-3, light epidotic; 3; 2-3;
893-895; 901-905, at 870-890, very full of seams but ophitic; at 890-1; ½ to 1 mm.
893 much seamed, slope of seams (12:9) 36°⅔ against core, i. e., perhaps nearly vertical, at 895-901 laumontitic.

From 843 to 846 somewhat seamed with calcite and altered; from 867½ much altered and rather coarse grained; from 875 to 881 epidote and calcite in streaks, at 905 apparently amygdaloid shows sediment, *a zone of alteration in trap* ? calcite and laumontite; at 978½-980 1″ prehnite seam, epidotic foot of trap or amygdaloid?

11. (Represented by fault).
Amygdaloid conglomerate d 3. 905-925
With some sediment; slope (5:9) 61° against core; about 60° dip.
From 923 to 925 breccia. This is Lode 2 repeated.

12. (Repeated) Ophite
Amygdaloid d 3. 925-930
Trap d 3. 930-1012
Grain at:
928-930, 944, 970, 995, 995-1005, 1012
1 to 2, 2–3, 3, 2–3, 1-2, 5 mm.

13. Ophite 117 (104)
Amygdaloid d 3. 1012-1030, lode 3 of mine cross-cuts.

With large patches of calcite to 1030 at which point is about 1′ brecciated. At 1035 to 1036 a few amygdules, and an epidotic altered, chloritic aggregate; at 1058 a thin vein of calcite.

Trap d 3. 1030-1129

At 1120 very epidotic with copper in small dots; at 1124-1128 a dark rock with patches of calcite.

Grain at:
1059-1070, 1075, 1092, 1108, 1119
2 mm., 2–3, 3, 2, 1 mm.

At 1075 to 1081 slips as at 1151 ft., about coarsest; at 1085 to 1086 relatively fresh, while 1075-1081 is green; at 1088-1090 a big slip at 61° against core about 60° dip.

14. Ophite 46 (41)
Amygdaloid d. 3 1129-1141

At 1129 epidote and copper; at 1131 calcite blotches surrounded by chlorite; to 1141 epidote with large calcite amygdules surrounded by chlorite.

Amygdaloidal melaphyre d 3. 1141-1146
Trap d 3. 1146-1175
Chlorite slip seams, and chlorite and calcite at 1151 ft.
Grain at:
1171, 1161, 1141-1155, 1134-1141
1 mm, 2 mm, obscure 2 mm?, fine grained.

At 1155 fine calcite seams at 66° to the length of the core; at 1160 epidote and calcite seams.

15. Sediment 3 inches at 1175 (0)
16. Ophite (45)

Amygdaloid? d 3. 1175-1207

Looks here and there like an altered, coarse grained ophite, with epidote, chlorite and copper; toward the base black and white passing into gray and white. Cf. Lode 5 of mine.

Cf. d 3. 1208 and d 2. 712
Trap 1207-1223+20+
The grain at:
1202, 1212, 1233 ft. is
3 mm., 2-3 mm., 2 mm.

Challenge drill hole 4. T. 52 N., R. 35 W. Was between Nos. 2 and 3 and never struck rock, though 65 feet and over deep.

Challenge drill hole 2. T. 53 N., R. 35 W. Elevation 53'.5 above datum. 200 feet west; 1056 feet south of the ¼ post between Sections 15 and 22. Drilled vertical. Dip of strata about 59° on the average.

Surface d 2. 0-125
1. Ophite d 2. 125-228 (50+)

Trap. Coarsest at 160 feet.

2. Ophite (faulted) d 2. 228-294 (160)

Amygdaloid, red, brecciated and very calcitic; Lode 1.

There is a 6-foot seam of brecciated quartz and epidote at 279 feet; at 289 feet a light colored streak of altered amygdaloid, with quartz and epidote, and at 294 to 296 there is copper in the altered amygdaloid.

Trap d 2. 294-549

At 334¼ there is 4 inches of chlorite, at 429 one foot of epidote alteration, at 458 a seam of reddish brown altered rock with seams of calcite and copper at 439. It is about as coarse as at 459.

But a fault is indicated between 460 and 549 as in the mine.

Cf. d 2. 228 to -549 with
d 3. 672 to 812

At 549 is a very fine dark trap.

3. Lode 2. Amygdaloid conglomerate d 2. 549-590 (16+)

At 552 feet amygdaloid conglomerate
" 575 " brecciated
" 589 " epidote with quartz amygdules
" 590 " fine grained trap
" 593 " amygdaloidal melaphyre and scattered amygdules to 599 feet, chlorite at 605 feet, possibly amygdaloid conglomerate. Cf. 822 and 843 feet.

4. Ophite (106)

Amygdaloid and amygdaloidal melaphyre d 2. 590-617

3 and 4 are counted as one lode in the cross-cut.

Trap d 2. 617-802

At 712 decomposed to epidote and chlorite so that the rock might be mistaken for amygdaloid.

At 754 a little epidote and seam of calcite.

The 185′ of trap at a dip of 60° would give (92) thickness, which is just what we find in the mine.

5.

Amygdaloid (Lode 3.) d 2. 802-821

Brecciated, epidote and calcite in patches.

At 823 feet chloritic; at 825 feet a brecciated chloritic seam.

Amygdaloidal melaphyre d 2. 821-838

Apparently with inclusions of amygdaloid.

Trap d 2. -878

Epidote at 878.

No. 2. 802 may be compared with

No. 3. 1020

Challenge drill hole 5. Elevation above datum 45′. (bridge over 13-mile creek on Ontonagon road taken as 100′). 200 feet east, 1928 feet south of the ¼ post between Sections 22 and 15, T. 53 N., R. 35 W. The hole is vertical so that it passes through the beds very-slowly.

From 3 to 5 in a direction E. 38° S. is 1390 feet, and this was nearly across the strike so that this shows the lowest part of the section.

Drift. Surface 143 feet.

1. Ophite d 5. 141-257=116+ 30+ more

The grain of this ophite is never much over 3 mm. for the augite, but the chemical composition is that of a normal ophite. The grain then would indicate a thickness of only (90) feet or so. This thickness is verified if this is the hanging of lode 7 in the 3rd level cross-cut. The thickness is 110 feet or less. Dip of the strata of 60° would mean that a 90-foot bed would intercept 180 feet on a vertical hole. The grain observations on the core boxes were—it begins finest

at	141-4;	144-153;	153-156;	161-172;	202;	215;	228;	234;	245;
	3;	2-3;	3;	3;	3;	2–3;	2;	1–2;	1;
	253;	257.							
	0.5;	contact mm.							

Sp. 20612-20 are of the drill cores used to illustrate the variation in grain in Plate 17 of the Annual Report of 1904, herewith reproduced (Pl. VI). They are typical illustrations of the typical mottled ophite with labradorite laths embedded in augite. The growth of the augite seems to have driven ahead the iron oxide and olivine, though the olivine is all changed to a mineral of low birefraction which seems to be chlorite. Iron oxides are magnetite and hematite. There is a little calcite. In Sp. 20618 the average breadth of the augite patches is 2.8 mm. Feldspar is about $Ab_2 An_3$. There are a few which occur up to 1 mm. across but it mainly runs from .1 to .2 x .05 to .02 and is smaller where it is embedded in the center of the augite patches. The olivine is about .12 mm. The magnetite varies from .5 to .16 mm.

The other sections are similar and the only variation is that of the grain. In 20619 the average breadth of the augite patches is 1.34. The feldspar is .2 to .8 x .02. In 20620 the augite is .75 mm. The olivines are still a few of them .1 mm., but mainly .04 mm. In 20620 individual grains of augite are set rather far apart, and there is a tendency noted by Lawson to compound aggregates of grains making difficulties in fixing the grain, in this transition zone. Comparing the coarseness of grain as measured in different ways we have the following table for the grain of the augite:

No.	Depth.	Distance from margin at 60° dip.	Apparent Grain. In drill core.	Apparent Grain. In thin section. Naked eye.	Apparent Grain. In thin section. Microscope.
20617	172	43	3 to 4	4.5	
18	202 An.	28	2 to 3	3	2.8
19	232	13	1 to 2	2	1.34
20	250	4	.5 to 1	1.5	.74
Contact	257	0	. . . .	. . . .	. . . .

The analysis of 20618 by F. K. Ovitz is as follows:

	%	Molecules.	Molecular %
Silica, SiO_2	45.21	.753	49.3
Titanic acid, TiO_2	2.14	.025	1.6
Alumina, Al_2O_3	15.85	.155	10.1
Ferric oxide, Fe_2O_3	9.55	.0595	11.6
Ferrous oxide, Fe O	4.37	.0608	FeO
Calcium oxide, CaO	10.36	.185	12.1
Magnesium oxide, MgO	7.25	.179	11.7
Manganous oxide, MnO	.89	.013	.9
Sodium oxide, Na_2O	2.47	.039	2.5
Potassium oxide, K_2O	.31	.003	.2
Phosphoric anhydride, P_2O_5	.165	.001	———
Carbon dioxide, CO_2	.48	.011	100.0
Sulphur, S	.07	.002	
Chlorine, Cl	.04	.001	
Moisture, H_2O	.47	.026?	
(Loss on ignition 1.36) (1.36-.47 to .48), H_2O+?	.41	.023?	
	100.035	1.5363	

By the quantitative classification this will be computed:

2. FeO + MnO = .062

3.b. $FeO\ TiO_2$ =.025 FeO left .037

c. $CaO\ P_2O_3$ =.001 CaO left .184

e. Cl after apatite of c is satisfied may be regarded as negligible. It is probably not in sodalite anyway but in the calcium chloride mine water and amounts to less than .001 mol

g. S with FeO=.002 S+.001 FeO. FeO left .036

h. CO_2 is secondary.

.155 Al_2O_3

4.a. .003 K_2O+.003 Al_2O_3

b. .039 NaO+.039 Al_2O_3 .042 Al_2O_3

.184 remainder .113 Al_2O_3

5.a. .113 Al_2O_3+.113 CaO=Anorthite

.071 CaO left

7.b. .037 FeO+.037 Fe_2O_3.=.037 Fe_3O_4

c. remainder .0595-.037 Fe_2O_3=.0225 Fe_2O_3

N. B. From the appearance of the thin section it is probable that part of the ferric oxide is due to secondary alteration. It is also not at all likely that the ferrous iron is all combined with it.

8.a. MgO=.179

FeO=.000 none left!

MgO+FeO=.179

=.071 with CaO+.108 MgO left

9.a. .108 MgO may be assigned to Mg SiO_3 or $Mg_2\ SiO_4$, but probably is present actually as augite or olivine.

11. in CaO Al_2O_3 $2SiO_2$ is .753 Si O_2

.223

12. in CaO MgO $2SiO_2$ is .142

17. in 2 (MgO) SiO_2 is .054

.419

balance is SiO_2 .334

.018+.234

18. .042 Al_2O_3 x 6=in albite+Or=.252 SiO_2

Balance .082

a. x+y =.108

x+y/z=.082

y/z =.026=olivine

x =.056 hypersthene

We have then:

	Mol.	%		
Orthoclase	.003	1.67		
Albite	.039	20.44	about $Ab_2\ An_3$	
Anorthite	.113	31.41	Salic	53.52
Diopside	.071	8.24		
		7.10		
Hypersthene	.056	5.60		
Olivine	.026	3.64	P+O 24.58	
				Femic 42.02
Pyrite	.001	.12		
Ilmenite	.025	3.80	M 16.98	
Apatite	.001	.34		
Magnetite	.037	8.58	A .46	

Hematite	.023	3.60
	.394	94.54

Class III Sal:fem=53.42:42.02 $<5:3$

Order 5 F:Q is infinite $>7:1$

Rang 4 $K_2O' + Na'_2O:Ca'O$ .042:.113 $<3:5 >1:7$

Sub rang 3 $K_2O:Na_2O$ 3:39 3:5

Salfemone-gallore-auvergnase-auvergnose is its class

According to Osann's classification.[1]

$S = 50.5 + 1.7 \quad = 52.2$

$A = 5.6 = (2.6\ Na_2O + .2\ K_2O + 2.8\ Al_2O_3$

$C = (10.4 - 2.8)\ Al_2O_3 \times 2$

$= 15.2$

$F = 4.0\ FeO + 8.10\ Fe_2O_3 + (12.4 - 7.6)\ CaO$

$+ 12\ MgO + .9 MnO$

$= 25.75$

$A + C + F = 46.6$

$a = 5.6 \times \frac{20}{46.6} \quad = 2.3$

$c = 15.2 \times \frac{20}{46.6} \quad = 6.5$

$f = 25.8 \times \frac{20}{46.6} \quad = 11.3$

The rock is $S_{52\cdot2}\ a_{2\cdot3}\ c_{6\cdot5}\ f_{11\cdot3}$

This would be of the gabbro norite family

"Sulitelma" type $S_{52\cdot5}\ a_{2\cdot5}\ c_{4\cdot5}\ f_{13}$

which stands next to the "Keweenaw" type $S_{51}\ a_1\ c_5\ f_{14}$

Neither the American nor Osann's classification brings out clearly what seem important points, the approach of the analysis to an augite formula $CaR_3Si_4O_{12}$ and that ¼ of the base is lime and another ¼ magnesia. The formula may be written in round numbers. CaO, MgO $(Na_2O\ FeO\ Fe_2O_3)\ (Al_2O_3\ TiO_2)\ 4\ SiO_2$

The proportion of lime is that common in hornblende.

The differences between this analysis and that of 15523 are within the range of imperfections in analysis and variations due to secondary decomposition. The top of this bed is presumably Lode 6 in the 3rd level cross-section (Fig. 59)

2. Ophite d 5. 241 (about 100)

Amygdaloid d 5. 257-317=40

Green cement and white amygdules to 261; streaked to 264; spotted to 271; greenish epidote to 274 to 275 black; to 284 irregular; to 297 much brecciated; to 300 compact; to 303 epidotic; to 312 brecciated, to 314 black paste with white amygdules; to 317 epidotic.

Trap d 5. 317-498

To 320 fine grained, compact; to 327 occasional large amygdules, then distinctly ophitic with augite mottles as follows:

334,	352,	367,	380,	405,	427,	446,	456,	467,	479,	488,
1,	2,	2,	2–3,	3,	3,	3,	2,	2–,	2–,	1,
495,		498.								

barely visible, contact.

This is presumably the foot of lode 7 (of blue print and Fig. 59, i. e, No. 8 of St. Mary's 1907 report), and hanging of Lode 8. It intercepts

[1] A. Osann, Versuch einer chemischen classification der eruptivgesteine. Tschermak's Mineralogische und petrographische Mittheilungen, XXI. Band, 5 Heft, 1902, p. 375.

212 feet there, 257 feet in the hole, which would imply a dip of 50°. Lode 7 gave Oct. 26, '08 a water with refraction=sp gr 1.015

3. Ophite 62 about (31)
   Amygdaloid d 5. 498-503
   Amygdaloidal melaphyre d 5. 503-510
   Trap d 5. 510-560
   Slight mottles from 556 on.

The group of small beds 3, 4 and 5 evidently correspond to the amygdaloids near together, 8, 9 and 10.

4. Melaphyre (ophitic) 49 about (25)
   Amygdaloid d 5. 560-565
   Trap d 5. 565-609

At 585-587 slightly amygdaloid; at 602 ophitic to 609, and at 605 very much brecciated.

5. Ophite
   Amygdaloid d 5. 609-623

609-620 very amygdaloidal, white amygdules on black ground, -623 altered streak and pseudoamygdaloidal, also 1 to 2 mm. ophite.

Trap d 5. 623-632

Mottles 1-2 mm. at 623 feet, altered at 626 feet, epidotic at 629 feet, then fine grained.

6.
   Amygdaloid d 5. 632-694

to 638 very amygdaloid, -654 seam light colored, full of calcite, to 661 same, much brecciated to 678, still light colored though not so much brecciated, to 684 darker gray and white.

685-690 fine grained.

Trap d 5. 694-738

At:

694,	700,	706,	713,	724,	731,	738
1,	1–2,	2,	2+,	2,	1–2,	contact.

731 to 735 has amygdaloid inclusions.

This very thick belt mainly of amygdaloid from 498 to 694 (196) feet, I made in the drill core 4 distinct flows, but in the mine 3rd level section evidently is lodes 8, 9 and 10 from 670 to 785 feet southeastward from the shaft which correspond at a dip of 59.5°. The division into flows is really uncertain, the small flows are amygdaloidal throughout.

7. Ophite
   Amygdaloid d 5. 738-740
   Trap d 5. 740-776

Compact with small chloritic amygdules at top from 740-745.

At 758 and 760 feet
mottles 2 mm. across

8. Basic sandstone and conglomerate 776-958

slopes against drill core:

At

780,	785,	792,	809,	821,	824–831,	851,	855
$11\frac{1}{2}$:8,	6:8 cross bedding,	6:8,	11:8,	11:8,	13:8,	12:8,	13:8

an average say $52\frac{1}{2}$° or leaving out two cross-bedding dips 56°.

This also agrees with the sandstone at the end of the 3rd level cross-cut.

The cross-cut also indicates flatter dips. At 841 are some basic fragments, and at 855 to 860 some large amygdaloid fragments, at 864 to 876 the sandstone has pebbles and boulders of ophite and down to 883 there are both ophite and (black and white) amygdaloid pebbles. It is very difficult to locate the exact base of this bed as the pebbles increase. This is one of the cases where it appears very strongly that the sediments are formed on an eroded surface of the underlying flows.

At 888 is a 2 mm. ophite, probably a boulder, for at 895 is amygdaloid and gray and white sandstone mixed. Thence to d 5. 903 is mainly amygdaloid. Thence to 907 mainly ophite with 1 to 2 mm. mottles, thence to 912 is amygdaloid, thence to 920 the core is in broken fragments of decomposed ophite, thence to 929 amygdaloid sediment, thence to 933 very epidotic trap with clasolites. The sedimentary base may be at 920 feet. To 936 is gray indurated (probably epidotic) sandstone with amygdaloid, to 938 are fragments mainly ophite, to 940 are very dark fragments and sediment; at 945 is a fine grained ophite; at 947 1 mm. at 949 a fine grained trap; at 952 brecciated fragments; at 954 fine grained ophite, at 958 a basic sandstone slope 7½ to 8, with some trap. I should not be at all surprised if on these boulders the hole had gone very crooked.

9. Ophite

Trap d 5. 962-996

at 962 to 971 mottles 1 mm., at 975-978 fine grained; at 984 to 996 fine grained with chloritic amygdules, basal amygdaloid?

?10. Ophite? d 5. 996-1045

(Drill hole seems to be following a clasolitic seam as from here on sediment occurs frequently).

At d 5. 996-1000 amygdaloid with clasolite

At d 5. 1004 fine grained, at 1006 fine grained with clasolite; at 1006 to 1008 indurated sandstone and between 1008 and 1012 much brown indurated sandstone, to 1015 fine grained trap, to 1022 veined amygdaloid, to 1024 fine grained clasolites, to 1026 coarser 1 to 2 mm. ophites mottled with laumontite, to 1028 the same, to 1045 a fine grained trap mainly, at the end brown sandstone.

11. Sediment, amygdaloidal conglomerate d 5. 1045-1090?

Epidotized brecciated, with amygdaloid enclosures at base 1045-1049, to 1062 breccia with sediment, amygdaloid and faulted pebbles.

Epidotic yellow-gray indurated sediment and amygdaloid to 1072, mainly fragments of amygdaloid to 1080, at 1084 and 1090 are trap and faint ophite.

12. Ophite ? d 5. 1090-1221

being eroded and decomposed and the drill following a clasolitic ? seam ?

Amygdaloid d 5. 1090-1139

Amygdaloid and sediment d 5. 1090-1095

Ophite and a 1-inch clasolite seam d 5. 1095-1101

Mainly amygdaloid d 5. 1101-1103

Brecciated d 5. 1103-1107

Fine grained d 5. -1113

Amygdaloid d 5. -1116

Very amygdaloid with clasolitic matter near 1119 & 1139

Brecciated d 5. 1139-1147

Trap d 5. 1139-1228

Down to 1170 cores badly broken up and decomposed at 1165.
At 1160 is a yellow green amygdaloid inclusion?

At 1187 feet and 1198 feet the ophite mottles are 2 mm., then it grows finer. At 1221-1235 it is amygdaloid. (A good deal of 12 may belong with the amygdaloidal conglomerate or there *may* be two flows).

13. Basic sandstone, slope 6:8 at the end 1235-1235.4?

This corresponds well with the mixture of sandstone and trap found near the end of the drill holes from the end of the cross-cut.

The Challenge third level cross-cut, referred to above and shown in Figure 59 (course S. 29° 4′ E.) is as follows:[1]

North end was in 1045 feet from shaft and hanging of lode 3 on March, 1909

Trap	0-123	(105)
Lode F "a little copper unpromising"	123-143	(18)
Trap	143-267	(105)
Lode E "Amygdaloid 7 of heavy copper in epidote"	267-295	(25)

This lode was also reached on the 4th level and drill hole 4 from the end of it gave considerable encouragement and a drill hole 5 cut it very obliquely. Dip of hole 75°, of lode about 61°. It was drifted on. In the foot trap were copper seams at a flatter angle of about 40°, at 363 and 375 etc., also in 4th level and drill hole 4.

Trap. Just west of a 10-inch seam of heavy copper	295-418	(104)
Amygdaloidal conglomerate	418-469	(45)

Lodes D and C (D amygdaloid 8 feet, amygdaloid conglomerate 24, felsitic 19 cut in No. 4 drill hole and level 4 with a little fine copper and a small mass)

Trap	469-506	(31)
Lode B. Amygdaloid cut in 4th level and drill hole B with speck of copper	506-526	(17)
Trap a 4 mm. ophite	526-623	(85)
Total from lodes C and D		(133)
Lode A or 1	623-648	(22)

Cut in 4th level and drill hole B (which dipped about 65° from horizontal). There was also a cross-cut in it (150 feet) from the drift following the fissure to the south and 450 feet southwest of the main cross-cut. Also a drill hole 3 followed it down from the 4th level 485 feet finding some copper in the foot. This may be lode No. 1 of the 1st and 2nd levels on the other side of a great slip which dips 87° 30′ to south and throws lode No. 2 down vertically 200 feet. This slip was followed along its strike S. 52° W. for over 700 feet with traps of varying grain (a sudden jump from 3 mm. to 7 mm. in one place on either side) finally finding lode No. 1 at a proper distance (150 feet horizontal from lode No. 1). There is, of course, no absolute assurance that lode No. 1 is lode A. Lode No. 1 has been supposed to be probably the Baltic lode, in which case the Amygdaloid conglomerate lode 2 would be the Baltic conglomerate. This is rather close under the felsitic conglomerate C and if so I should suspect great displacement in the fissure, and that the Baltic lode continues slowly to rise in horizon south from the Champion Copper mine. The slip was found at the end of the 2nd level about 175 feet from the shaft at right angles to the strike with a nearly vertical (89°) dip.

The tests of saltness of the water given in the chapter on mine waters show dis-

[1]There is a rise in the cross-cut (which is about 700 feet below collar of shaft) going south, from −125 (below Portage Lake) to −102.93 at the drill hole. The distances here given are reduced to horizontal. Two drill holes at the south end dipped respectively 29° and 35° from the horizontal to the southeast, thus giving the dip of the beds they cut. See annual reports of St. Mary's Co. I have also visited the property

tinctly the lower salinity near the fissure. It is, however, a fair question whether this may not be a dilution due to water following the fissure since mine pumping began. I do not think this is wholly true. We have 0.09 to 0.25 grams per liter chlorine near it on the 3rd level.

Trap to Lode 2	648-807	(138)

A doleritic 7 mm. ophite

Lode 1 was found only on the 1st and 2nd level cross-cuts horizontally above the amygdaloid conglomerate, Lode 2 dipping about 60°. On 1st level Cl was 0.040, Ca 0.033 grams per liter.

Lode 2 Amygdaloid conglomerate	806-843	(32)

Cut and repeated by the fault on the 3rd and 4th levels, also found in 2nd level. Has 1.00 grams Cl and 0.13 Ca on 3rd level per liter, 2.3 grams Cl. and .315 Ca on 4th level per liter.

To repetition of Lode 2 Trap	807-920	(98)
Lode 2.	920-940	(17)
Trap under Lode 2 (all these traps are of ophite type)	940-1045	(98)
Lode 3. Amygdaloid	1045-1060	(14)

With a little fine copper on 2nd level, also cut on 4th level, with 5 grams Cl. and 1.8 Ca per liter

Trap	1162-1196	(33)
Lode 5 Amygdaloid. Cf. d 3. 1120-1128	1196-1222	(139)

Had some copper on 3rd and also on 2nd level with epidote, and a 350-foot drift was cut on 4th level. On 2nd level had 6.1 Cl and 2.00 Ca in grams per liter, on 3rd level 6.8 Cl. and 2.37 Ca. The strike here appears to be S. 32° E.

Trap	1222-1376	(134)

From this point on the belts were only cut in the 3rd level

Lode 6	1376-1391	(13)

Fair stamp rock? with 7.35 Cl and 2.6 Ca in grams per liter

Trap	1391-1507	(101)
Lode 7	1507-1550	(38)

Contains copper, water saline, refraction=Sp. Gr. 1.1

Trap	1550-1730	(157)
Lode 8	1730-1742	(10)
Trap	1742-1770	(25)
Lode 9	1770-1780	(9)

Very salty, Cl 63, Ca 2.06

Trap	1780-1800	(17)
Lode 10	1800-1831	(27)

A drift was run northeast on this and met a slip which cut the hanging trap of this but in the cross-cut was 10 feet above No. 9, thus like other slips showing a strike farther from north and south. On this there was "some fine and some heavy copper" and if we called the heavy trap above 8 the Mabb ophite this might be the Baltic lode. Cl. was 6.4 and Ca. 2.08 grams per liter in the water.

Trap	1831-1870	
Lode 11	1870-1920 or 1926	(25)

Some heavy copper, includes 8 feet of trap

It is possible that Lodes 10 and 11 represent the Baltic

Trap	1900-2078	(157)
Lode 12	2078-2108	(26)
Trap	2108-2210	(89)
Basic sandstone	2210-2240	(26)

Can this be Conglomerate 3?

End of drift 30 feet on. Cf. end of Hole 5

Trap (completed in drill hole 5)	2210-2295	(74)
Lode 13	2295-2317	(18)
Trap	2317-2426	(105)
With numerous clay seams		
Brown sandstone with conglomerate	2426-2454	(24)

This is the last belt with any thing like normal dips. The two drill holes from this on show very numerous seams and flat dips. The Torch Lake section shows similar phenomena.

Trap rock with clay seams	160-260
Sandstone	260-285
Conglomerate and broken trap	285-305
Sandstone	305-315
Trap	315-375

Sandstone, the Eastern or Jacobsville, ...at 367 feet in one hole and 406 feet in the other.

We see then that in the top of No. 7 we have 655 feet of beds without conglomerate including beds that may be matched with the Winona lodes, and that in the bottom of 7 and top of 6 we have a bunch of conglomerates which are quite thick. The northwest end of the cross-cut and drill hole 3 also includes conglomerate. The lower part of Hole 6, Hole 3 and Hole 2 and the uppermost part of Hole 5 down to 776 feet and the central part of the cross-cut show a broad belt of ophites with practically no felsitic sediment, only amygdaloid conglomerate, which may correspond to the 1201 feet in the Isle Royale section between Bed 38, Conglomerate 4 and Bed 61, Conglomerate 3. Then we have heavy sediments again such as generally occur near the base of the series, from Conglomerate 3 down. The big ophites below Holes 7 and 11 are as identifiable with the Mabb ophite as any, but they are not as coarsely mottled. In that respect Belt 10 of No. 3 to 796 feet, would be as near it. But even if the felsitic conglomerate of Belt C is not persistent and important and be taken to be Conglomerate 4, No. 38 of the Isle Royale section, this belt over Lode 2 is much too near. If we call the Amygdaloid conglomerate of Lode 2 equivalent to Conglomerate 4, C and D might be 5, and the sandstone at the E. end of the cross-cut Conglomerate 3. Lode 10 would then be most nearly at the Baltic horizon.

Limestone Mountain (*Figure 48*).

Less than ten miles from the region of the Winona mine are outcrops of paleozoic limestone mentioned already by Foster and Whitney and Jackson and Rominger but more carefully studied by W. L. Honnold,[1] which deserve a word of mention for the light they throw upon the date of the Keweenaw fault and the physiographic conditions. There is quite a hill on Sections 13, 14, 23 and 24 T. 51 N., R. 35 W., known as Limestone Mountain, and a smaller exposure on Section 7 to the northeast.

Limestone here occurs plainly of Trenton age as shown by the following list of fossils identified by W. F. Cooper. The Niagara occurs only at the point marked N in Fig. 48.

Ss. 13481 to 13643 were collected by W. L. Honnold.

Ss. 16567 to 16616 were collected in a trip by L. L. Hubbard, A. E. Seaman and A. C. Lane.

13560 Orthoceras vertebrale
13555 Orthoceras undulostriatum

[1]Wadsworth, M. E. Origin and Mode of Occurrence of the Lake Superior Copper Deposits Trans. Am. I. M. E. xxvii 669, also A. J. of S. XLII (1891, p. 171, and my annual report for 1903, p. 178.

13549, 13552	Trochonema beloitenses
13565	Pleurotomaria subconica
13574	Orthoceras
13564	Orthoceras (vertebrale) darus
13596	Cypricardites ventricosus?
13547	Cypricardites ventricosus
13556	Cypricardites obtusus
13567	Buthiatrephis
	Cypricardites obtusus
13586	Cypricardites {megambonus, niota}
13545	Modiolopsis lata
13597	Cypricardites latus?
13579	Cypricardites megambonus
13584	Cypricardites megambonus
13587	Cypricardites glabella
13582	Cyrtodonta billingsi
13557	Cypricardites amygdalinus
13558	" "
13572	Cuneamya subtruncata
13601, 13605	Pentamerus
13576	Rafinesquina alternata
13577	Orthis testudinaria

The hill to the northeast on Section 7 has a different but characteristic early Palaeozoic fauna (Ss. 16596 to 16616). I feel sure that not only Trenton but Niagara limestone occurs in the main hill (and is represented by Ss. 13601 to 13605, 15671, etc.) about 925 to 1000 paces north and 25 to 200 west of the southeast corner of Section 23, T. 51 N., R. 35 W. at the point marked N. in Fig. 48. Not merely the Pentamerus but the peculiarly white and sugary lithologic character are suggestive. The main hill rises to a height of about 1000 A. T. from flat clay plains which are about 695 A. T. Of course, these limestones are harder than the surrounding sandstones and may be to some extent forms like Mt. Monadnock.

In Fig. 48 is given not only a sketch map of the immediate neighborhood, but the section prepared by W. L. Honnold, east and west along the section line BB, and also his section showing the pits which he had dug, exposing the contact between the limestones and the underlying sandstone, 10 paces north and 575 feet west of the southeast corner of section 14. There is a possibility of a minor unconformity and Honnold queries whether the sandstone exposed is the Madison sandstone with the Mendota limestone beneath unexposed or not.

§19. GLACIAL PHENOMENA. (FIG. 49.)

Near Stonington and Heron Lakes we get to the west side of the heavy belt of drift. It is worth noting that whereas the striation and motion around Houghton and north seems to be from Keweenaw Bay, from a little south of east, on the other side of this belt of drift, it is from the northwest. It thus appears that this heavy line of drift was formed or pushed up between two different lobes

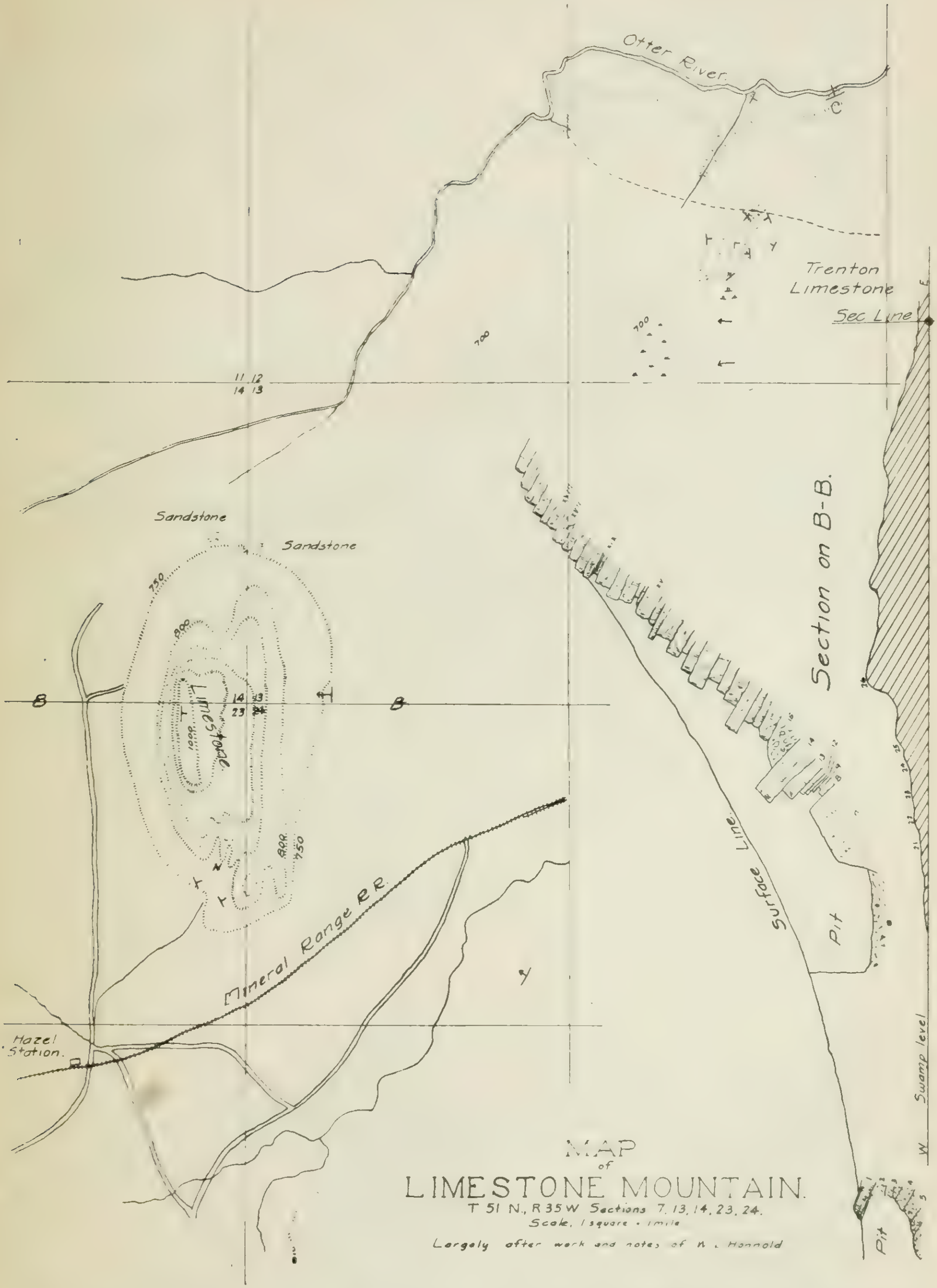

Fig. 48.—Section of Limestone Mountain. The 50-foot sketch contours refer to sea level. The line B B marks position of cross-section, the letter N the position of the Niagara.

of the ice from the Keweenaw lobe and the Chippewa lobe. See Figure 49, reproduced from Figure 16 of the Annual report for 1907.[1] I should add, what a figure cannot show so well, that the position of the ice on the east side and on the west was not coeval. Heavy deposits of clay around Mass City and elsewhere in the Ontonagon valley suggest that the ice came first from the

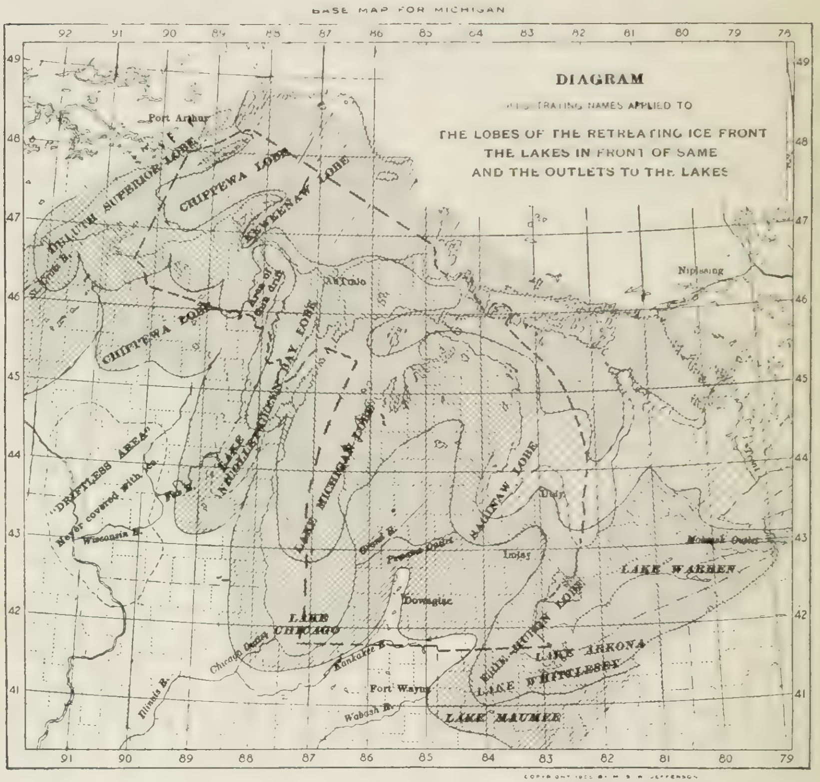

Fig. 49.—Diagram illustrating names applied to lobes of the retreating ice front and the lakes in front of the same.

northwest side, the Keewatin center damming up a lake (in which copious red sediment of slip clays settled) on the southeast side of the range, while at its very latest stage, the ice retired toward a western Labrador center, damming up a lake on its western front which has left its scorings all along the front of the range on the west side, even as much as 650 feet above its present level.

Along the south part of the Range, therefore, a deep valley which once followed nearly along the line of the Keweenaw fault is nearly

[1]See also Leverett in Publication No. 7, 1910.

filled to the brim with glacial deposits—several hundred feet of glacial deposits before reaching bed rock are not infrequent. This seems to have been made by side streams to the streams that crossed the range transversely in a style of drainage much like that now found near the New Jersey traps. There is a great outwash plain of sand and gravel dotted with lakes that have no visible outlets, that seep away through the sands and mark places where huge masses of ice were left swathed in sand and gravel as the ice retired, to slowly disappear. This plain extends west from the front of the Labrador ice and is well marked around Toivola and the northwest part of Plate XI. This big moraine seems to cross the Copper Range near Portage Lake and make the heavy till deposits east of Hancock, and around Lake Annie. A later stage is the other side of the Otter in T. 52 and T. 53, R. 34 W.

§20. ELM RIVER, ERIE AND ONTARIO. (PLS. XI AND XII.)

The outcrops begin to appear once more southwest of this moraine and near the north line of Section 32 (Pl. XI) is a conglomerate which may well be the uppermost of those in the Challenge Hole 7. In that case a conglomerate near B. M. in Section 20 near Stonington would be about 3,200 feet above it horizontally at right angles to the strike, and about 2,800 feet in thickness if the dip is 61.5°. This is a thickness not unlike that of No. 9 above No. 8 of the Arcadian, but in the Winona section would more nearly correspond to the thickness from Conglomerate 8 up to the Johnson Creek conglomerate,—that at the Shawmut on the Elm River property. In the south part of Section 31 is a lower conglomerate. In Section 6 begins a conglomerate with very fairly continuous outcrops (Pls. XI and XII) that can be traced thence as shown across the Elm River (Contact Copper Co.) property.

Here we have once more extensive drilling and with the help of a cross-cut on the mine from above the Winona lode and this conglomerate (8) down into a belt, drill holes 5 and 6 in which there are few conglomerates but heavy ophites, which seems recognizable as that near and above the horizon of the Mabb ophite and shortly above Conglomerate 3. The record for which we owe acknowledgments to H. B. Fay, J. Chynoweth and S. Chynoweth, and G. S. Goodale, is as follows:

Beside the drilling there were cross-cuts from No. 1 shaft as shown and from No. 8 shaft from No. 6 conglomerate to and including the beds of drill hole 5. The old Shawmut shaft is close above a conglomerate. There is another whose

base is below it	1750	(1600)
Thence to No. 2 drill hole is	1320	(1200)

To the Winona lode is	1800
To the base of Conglomerate 8	2460 (at 67.5° dip) (2270)
Base of Conglomerate 8 to top of No. 3 hole	130
Base of Conglomerate 8 to base of No. 7	460
Base of Conglomerate 7 to top of No. 4 hole	250
Base of Conglomerate 7 to base of No. 6 conglomerate	560
Base of No. 6 conglomerate to top of No. 5 hole	270
Base of No. 6 conglomerate to top of No. 6 hole	780
Base of No. 6 conglomerate to base of "Elm River" conglomerate	1250
Base of No. 6 conglomerate to base of "Wyandotte"	2130

Abstract of Elm River section

Drill hole & No. of belt.		Thickness.[1]		
Ed 2 b	1	(130)	130	Ophite, feldspathic (Minong trap type)
	2	(105)	235	Feldspathic M. Sc. Am.
	3	(148)	283	Doleritic ophite
	4	(74)	457	Melaphyre, feldspathic
	5	(41)	498	Melaphyre, feldspathic
	6	(27)	525	Am. brecciated
	7	(44)	569	Am. feldspathic
	8	(120)?	689	Am. feldspathic M.
	9	(106)	795	Ophite dense
	10	(121)	916	Ophite with Sc. Am.
	11	(45)	+961	Ophite.

Lapping drill holes		Thickness.	Cross-cut Running measurement.	
		(62)	23	Winona lode
	From the foot of the Winona		total 979	(922)
			43 Trap	
			11 Am.	
	lode to	(48)	40 Trap	
			18 Am.	
	the top of	(99)	87 Trap	
			19 Am.	
	Conglomerate 8 (283) 308	(103)	90 Trap	
Ed 1 b 1 55+	Conglomerate No. 8?	(194)	205 Cong. top	
Hanging of Winona lode above base of Conglomerate No. 8		(506)		

[1]Most of the drill holes were at an angle of 30° with the horizontal and supposed to be at right angles to the beds. This is probably so nearly true that little correction for the thickness is needed. In Hole 2, for instance, 974 feet is reduced to (961). The term sc. (scoriaceous) in these records is synonymous with what I have elsewhere called amygdaloidal conglomerates.

Lapping drill holes.			Thickness.		Cross-cut Running measurement.
	2	48	Feldspathic Am. and Trap	(42.5)	105 Am. 35 Trap
	3	171	Ophite Sc. Am.	(131.5)	24 Am. 115 Trap
	4	74+ 348	Conglomerate (118'? thick) No. 7	(63)	23 Am. 45 Trap
Ed 1 b	1	32 32+60?	(Conglomerate just above?) Ophite	(91)	17 Am. 79 Trap
	2	23 ∧	Am. and trap Sc.	(79)	4 Am.
	3	74	Ophite feldspathic		80 Trap
	4	12	Trap	(47)	23 Am.
	5	50	Am. and trap Shaft A		11 Shaft
	6	21	Am.		40 Trap
	7	85	Conglomerate basic sc. with ss No. 6?	(118)	126 Cong. 6
		265 ∨	Base to base of No. 8?	(552)	(? or 7)
	8	31	Am. feldspathic		20 Am.
	9	112	ophite Sc. Am.		
	10	60	(Conglomerate ?) M	84+69+Trap	
	11	13	Am.		
Ed 4 b	1	50±(<50)	Ophite,—veins of sandstone in the bottom		
	2	203 494	Sandstone and conglomerate No. 5. Base from base of No. 8	(1085)	
	3	185	Ophite, sc. top 130' doubtful		
	4	52	Am. and fine grained ophite, epidotic at bottom		
Ed 5 b	1	23+(30+)	Ophite		
	2	169	"		
	3	137	" sc. Am.		
	4	86	"		
	5	180 (40)	" sc. A		
Ed 6 b	1	17	Epidotic		
	2	36	Amygdaloid, thin, red,		
	3	45	brecciated and epidotic		
	4	188	Ophite, brecciated top with		

		much sandstone mixed marked ophite	7
5	149	Am. clasolitic and sediment?	

Elm River[1] *Copper Company.* Shafts No. 1 and 2 are supposed to be on Winona lode. Shafts No. 3 and 4 are supposed to be on the Shawmut amygdaloid. Shaft No. 5 (A of these notes) is on an amygdaloid about 1000 ft. E. of the Winona lode.

Elm River drill hole 2. In section 11, near the pond and showing the section above the Winona lode. From its position it should be about 600 feet above it, at an angle of 30° to the S. E. like the rest of the holes. The first box of samples were somewhat misplaced but began with Ed 2 b 1, 0? to 132-amygdaloid, then porphyritic, and fine grained feldspathic ophite, rather feldspathic at 49 feet, and the second box begins with long cores of hard trap and an ophitic texture only appears at 70′ 1″ to 70′ 4″, reminding one of the Minong trap. Cf. Central mine Beds 97-112 and Torch Lake, No. 59. From 76′ 9″ to 78′ 3″ is plainly feldspathic ophite and at 86′ 9″ the mottles are 2 to 3 mm. broad, but it never gets very coarse grained. The bottom is at 132 feet.

Thickness 132 (130?) feet.

Ed 2 b 2, 132-239. Begins with a scoriaceous conglomerate and some amygdaloid, becoming yellow and white epidotic, scoriaceous, with copper in the epidote, at 177 to 218 it is feldspathic and fairly fine grained with a trace of ophitic texture.

Thickness 107 (105) feet.

Ed 2 b 3, 239-390. 5 mm. ophite, coarse porphyritic amygdaloid to 245 feet, with patches amygdaloidal at 259 and 291; near by, however, is a coarse doleritic texture with feldspar tablets 3 to 4 mm. broad. At 322 feet the mottles are about 5 mm. broad, by 345 feet they begin to get finer. At 362 feet there are veins (1:10 & 12:10) one set of which may be nearly parallel to the bedding. Dark at the bottom (382 feet).

Thickness 151 (148) feet.

Ed 2 b 4, 390-466. Melaphyre, feldspathic, and glomeroporphyritic, small amygdules down to 411, coarse amygdules at 422 to 444. This might be classed as a broad amygdaloid belt.

Thickness 76 (74) feet.

Ed 2 b 5, 466-508. Melaphyre, feldspathic and amygdaloidal, blotched at 482 and 492, and veined and seamed which makes it difficult to determine the boundaries of the flows here.

Thickness 42 (41) feet.

Ed 2 b 6, 508-530. Melaphyre, amygdaloid, brecciated, altered and seamed, and porphyritic in texture.

Thickness 28 (27) feet.

Ed 2 b 7, 530-575. Melaphyre, amygdaloidal and feldspathic. Epidote seam at 545 and long cores of compact trap beneath.

Thickness 45 (44) feet.

Ed 2 b 8, 575-697. Melaphyre, feldspathic and with heavy amygdaloid down to about 600, more or less streaked, the dip of the vein against core barrel (1½:10 or 2:10) may indicate vein dipping 68.5° to 71°, or nearly parallel to the bedding while another set of seams (30:10) may be nearly at right angles to the same.

Thickness 122 (120) feet.

Ed 2 b 9, 697-805. Ophite. Hanging of Winona lode (?). The top is a fine

[1]Now contact Copper Company.

grained marked amygdaloid, and below it is a fine ringing dark trap, with seams and amygdules perpendicular to the drill hole (and probably nearly parallel to the top), while there are some white seams, more nearly (C0:10) parallel to the drill hole. At 720 the augite mottles are 2-3 mm. broad, at 737 3 mm., below as much as 5 mm. perhaps, at 756 3 mm., and 774 2 mm.; by 786 it is very fine grained black.

Thickness 108 (106) feet.

Ed 2 b 10, 805-928. Ophite. A marked scoriaceous amygdaloid for the first 11 feet, there is a white and green amygdaloid from 5 to 10 feet, and streaks of amygdaloid below.

At 842 to 852	the	mottles are	2 to 3	mm. broad.
At 877	"	" "	3 to 4	" "
At 883	"	" "	3	" "

Then they grow distinctly finer, being $1\frac{1}{2}$ and 1 mm. between 902 and 928.

Thickness 123 (121) feet.

Ed 2 b 11, 928-974. Feldspathic ophite with about 12 feet of amygdaloid on top, and below a feldspathic ophitic texture.

Thickness 46 (45+) feet.

Above the three heavy belts of ophite in the bottom of Ed 2 came a series of more amygdaloidal and feldspathic and generally thinner belts.

Elm River drill hole 7. On the S. E. corner of Sec. 6, T. 52 N., R. 35 W., was put down 250 feet through overburden, mainly sand, though there was a 14 feet core of mica schist, a boulder, without striking bed rock, and at the center of Section 6, T. 52 N., R. 35 W., a hole at an angle of 50° found 350 feet of "overburden" drift.

Elm River drill hole 1. (Ed 1). Put down at an angle of 30° about 600 ft. N. W. of the W. $\frac{1}{4}$ post of Sec. 12, T. 32 N., R. 36 W. Cf. Wyandotte Mining Company's holes 5 and 7. From 0 to 40 ft. was overburden of sand, etc.

Ed 1 b 1 96′ 6″

Conglomerate with well rounded pebbles often red felsite and also dark, with much calcareous cement, especially from 69 ft. down.

Thickness 56+[1] (55)

Ed 1 b 2 96′ 6″-144′ 10″

Amygdaloid and trap, never coarse grained, feldspathic, amygdaloid for the first 6′, and along at 131 coarsely feldspathic and green. Amygdules and amygdaloid white.

Thickness 49 (48)

Ed 1 b 3 144′ 10″-289″

Ophite, with scoriaceous epidotic amygdaloid the first 16 ft., seams at right angles to drill holes, i. e., parallel to the bedding at 203′ 8″ and a vein at 207′ 3″ to 209′ 7″, also at 237, 239, 242, 247, 250, 255, 256 to the bottom. The bottom 60′ just overlying the conglomerate is evidently a good deal shattered. At 223′ 7″ the augite mottlings are 2 to 3 mm. broad, the ophite texture being apparent to the eye from about 203 to 255 and more. It is clearly finer grained at 277.

[1]True thickness, since the dip of the strata is supposed to be about 70° and the hole is at 30°, with a horizontal plane, or 80° with the strata, is about the same as the apparent within the limits of error which may be increased by deviations from the hole. The correction factor is from .978 up. We have subtracted 2% for correction.

Thickness 174 (171) ft.

Ed 1 b 4 289-363

Conglomerate, basic conglomerate at the top, with rounded pebbles and basic cement, and some (378 ft.) big felsite pebbles.

Thickness 74+ (72+)

This is correlated as Conglomerate 7, outcropping near the quarter post. W. J. Uren says it is 118′ thick. I think, however, that it is one which must be interpolated as 7½.

Elm River drill hole 3. (Ed 3). Also at 30° or at nearly right angles to the strata and is located 250′ S., 300′ W. of the center of the N. W. ¼ of Sec. 12, T. 52 N., R. 36 W. It is said to begin in a bed of ophite, which lies just under the conglomerate cut in diamond drill hole No. 1. The holes do not therefore overlap enough to give us a section independent of the strike of the beds and surface exposures and I think in reality there is a gap from conglomerate 7½ to conglomerate 7, unrepresented in the cross-cut, for on Ed 3 b 5, 141 to 191 feet a shaft was put down, supposedly following the dip of the lodes, and at a depth of 250′ cross-cuts 255′ S. E. and 979 N. W. were driven. Beginning with the shaft the section scales to N. W.:

	Feet along the cross-cut.	Total from the shaft to N. W.	Thickness.
Trap	80	80	74
Amygdaloid	4	84	78
Trap	79	163	150
Amygdaloid	17	180	167
Trap	45	225	209
Amygdaloid	23	245 drift on this	227
Trap	115	360	333
Amygdaloid	24	384	356
Trap	35	419	388
Amygdaloid	10	429	397
Conglomerate	205	634	587
Identified by W. J. Uren as No. 8.			
Trap	90	724	674
Amygdaloid	19	743	694
Trap	87	830	770
Amygdaloid	18	848	788
Trap	40	888	822
Amygdaloid	11	899	834
Trap	43	942	877
Winona lode	23	965 above cong. 8.	898
Width of shaft	11 feet	976	
979 from the foot of the shaft		965	
...3′ of accumulation of error in scale.			
The section to S. E. is:			
Trap	40		10
Conglomerate	126	166	37
Identified by Uren as No. 7.			
Amygdaloid	20	186	117
Trap	69	255	

Ed 3 b 1. 0 to 32 ft. Ophite; base of a bed which occurs just under a conglomerate it is said, by Capt. S. Chynoweth. The coarsest mottling is 1 to 2 mm. at the beginning, say at 8 feet.

Thickness 32+

Ed 3 b 2, 32 to 55. Small amygdaloidal melaphyre, a scoriaceous amygdaloid with intermixed sediment showing that the dip is practically at right angles to the drill hole at 32 to 35 ft. More massive below 37 feet.

Now Ed 3 begins in a well-marked ophite, which is not less than 32 feet thick, probably more than twice that, 140′ above the level of shaft A and 212′ (208) above a conglomerate. At any probable dip it would be the 79-foot trap, then Ed 3, 32 to 142 corresponds nearly to 84 to 163 feet in the cross-cut, or 139 feet, implying a dip of 72°, as good an agreement as could be expected. Or if we take the largest range of correlation for Ed 3 (32 to 297) we have for the dip 67° 53′ or say 68° which is perhaps as accurate a dip as we can get, since the slope of the adit and the rolls of the strata affect it somewhat.

Ed 3 b 3, 55 to 129. Feldspathic ophite, with patches of amygdaloid scattered through, possibly the same as the flow above. Epidote alteration at 90 to 92 and 106, brecciated, pseudamygdaloid at 118.

Thickness 74 feet.

Ed 3 b 4, 129 to 141. Fine grained melaphyre.

Thickness 12 feet.

Ed 3 b 5, 141 to 191. Amygdaloid. Very well marked at the top, fine grained and seamed throughout. On this lode shaft A was sunk (or No. 5), and from this a cross-cut driven east and west, which enables us to fill the gap from No. 3 hole to No. 1 hole.

Thickness 50 feet.

Ed 3 b 6, 191 to 212. Amygdaloid.

Thickness 21 feet.

Scaling from the cross-cut section prepared by the engineer there is for the amygdaloid followed by the shaft 11 feet and 40 ft. for the trap 51 feet which corresponds in part to Ed 3 b 5 and Ed 3 b 6 perhaps. Of course the exact determination of the limits of the amygdaloid is uncertain.

Ed 3 b 7, 212-297. Conglomerate, scoriaceous, pebbly, basic, with much sandstone at 244 and 295, the bedding at right angles to the drill holes.

Thickness 85 feet.

This in the cross-cut east from shaft A is given as 126 feet which would imply a much flatter dip angle than is possible. S. Chynoweth told me that they struck this within 5 feet of where they expected in putting in the cross-cut.

Ed 3 b 8, 297-328. Amygdaloid, feldspathic, fine grained, porphyritic, red.

Thickness 31 (30) feet.

Under the conglomerate in the cross-cut east from shaft A is amygdaloid 20 feet.

Ed 3 b 9, 328-442. Ophite. Beginning with a well-marked scoriaceous and clasolitic amygdaloid down to 345 (17 feet), then veined to 349, epidotic to 632, and brecciated and veined to 381, fissured at 406 and 432 also. The augite mottling is 1 to 2 mm. across at 397, 2 mm. at 408 to 411, and at 413 is 2 to 3 mm. across.

The cross-cut section east from shaft A from 255 feet shows trap for the last 69 feet.

Thickness 114 (112) feet.

Ed 3 b 10, 442-503. Melaphyre. The top has apparently a little conglomerate and is then amygdaloid for about 30 feet (471), at 483 light yellow-gray, feldspar laths prominent, altered, then finer, and at 501 fine grained black.

Thickness 61 (60) feet.

Ed 3 b 11, 503-516. Melaphyre. Amygdaloid, but at the end augitic, compact, trap.

Thickness 13+

Elm River drill hole 4. (Ed 4.) At an angle of 30°, along the road from the location to the station, the conglomerate Ed 4 b 2 being, it is supposed, the same as that exposed in the cut of the Copper Range R. R. back of the Elm River station. It is about 600 feet S. and 125 east of the center of the N. W. ¼ of Sec. 12, T. 52 N., R. 36 W. I should not be surprised if this hole was quite crooked. The angles of dip in the drill hole indicate that.

Ed 4 b 1, 1-51. Ophite. As the grain is growing coarser at the beginning going down we may be reasonably sure that the whole thickness of the belt is less than 102 feet. At 31 the mottlings are about 1 mm. broad, and still visible at 40. Clasolitic veins of sandstone appear in the bottom part.

Thickness 51+ (50+ and 100-, about 75 feet probably).

Ed 4 b 2, 51 to 258. Sandstone and conglomerate. First 10 feet sandstone; bedding of sandstone against cores about (4:8) 53° 30′; perhaps nearly vertical. With felsite and basic pebbles, large at 201, and calcitic cement, passing into a scoriaceous conglomerate. At 232 there appears to be bedding at an angle with the drill cores of 43° 10′. The line between this and the belt below is quite uncertain.

Thickness 207 (203).

Ed 4 b 3, 258-447. Ophite with scoriaceous conglomerate top, red seams (clasolites) of shaly sediment at intervals to 388, a black amygdaloid with red sediment being predominant type, but there are epidotic seams 319-328 and 350 and pebbles of ophite at 350 and labradorite porphyrite at 388. Red shale at 367 is at an angle (4 to 6:8) of about 50° with the drill cores. The ophitic texture is marked from 395 down, and is very fine grained by 447.

Thickness 189 (185) feet.

Ed 4 b 4, 447-500. Melaphyre, amygdaloid, epidotic from 492 to 500; this may be the top of the same bed as Ed 5 b 1.

Thickness 53+ feet (52+)

Elm River drill hole 5 (Ed 5). At an angle of 30° with the horizon and about 650 feet north and 650 feet west of the center of Sec. 12, and lower than Ed 4. It probably begins in the belt in which Ed 4 leaves off, Ed 4 b 4. There is 25 feet of overburden sand, etc., and apart from altitude the first samples should correspond about to Ed 4, 450 feet.

Ed 5 b 1, 25-48. Ophite, coarsest mottling at beginning 3 mm. broad, growing finer.

Thickness 23+ (probably not less than 50 feet).

Ed 5 b 2, 48-179. Ophite amygdaloid to 61, then as is often found the case at the margin of an amygdaloid, an epidotic band to 64 feet, the ophite for a way (68) is altered and light colored. The mottles of the ophites have the following breadths:

85	97	114	124	140
2	2–3	3	3–4	5

It is clearly mottled down to 169 feet.

Ed 5 b 3, 179-319. Ophite, amygdaloid, clasolitic, and scoriaceous to 192 feet, and fading out between 196 and 201 but by 226 plainly mottled, at 241 mottles

3 mm. broad, and growing coarser to 267, where it is seamed. At 300 it appears finer, at 310 is veined to 319 and epidotic to 325. There is here apparently a shear zone which the drill hole traversed to another belt (or the same one repeated) without any typical amygdaloid such as occurs on top of flows. The grain indicates also either that part of the flow has been cut out, or that one flow followed before the previous one had been cooled.

Thickness 140 (137±)

Ed 5 b 4, 319-407. Ophite. Epidotic to 325, and fine grained to 333, coarsest from 354 to 371. There is an epidote seam at 382.

Thickness 88 (86+)

Ed 5 b 5, 407-488+. Ophite, beginning with a well-marked scoriaceous amygdaloid or conglomerate to 465, epidotic at 412 to 427, brecciated at 421 and 433. It is said that this lies under the railroad track with 30 feet of overburden. The mottles increase to the bottom, being 2 mm. broad at 472 and 2 to 3 mm. at 486 feet.

Thickness 81 (80+) feet.

Ed 5 has no well-marked conglomerate. Heavy ophites appear predominant, but there are scoriaceous tops.

Elm River drill hole 6 (Ed 6). Put down at 50°, the rest at 30°. The reduction factor will therefore be, if the dip is 70°, the sin (180°-70°-50°)=.866. There was a heavy overburden, for this lies across the railroad southeast of Elm River in the valley, 200 feet west and 300 feet north of the center of the Sec. 12, T. 52 N., R. 36 W.

Ed 6 b 1, 132 to 149	Thickness	17	(17) feet.
Ed 6 b 2, 149 to 186		37	(36)
Ed 6 b 3, 186 to 231		46	(45)

This hole begins in an epidote seam like Ed 5 b 5, at 412 ft. It remains epidote for more than 17 feet, is a red amygdaloid at 157 and 159, brecciated 177 to 181, then more compact but amygdaloidal at 186 and brecciated and still epidotic at 190.

Ed 6 b 4, 231-425. Ophite. A red and white marked, brecciated amygdaloid for the first 20 feet down to 254, at 260 and 268 veined and seamed and from 274 to 283 epidotic. Thereafter the rock is more compact and the mottles plainer.

At	283,	290,	302,	330 ft. the mottles are	
	1–2,	2,	3,	4 mm. broad	
Distance from bottom	123,	117,	107,	82 and coarsest about 337 feet?	
At	357,	374,	391,	402 ft. the mottles are respectively	
	6–7,	4,	2,	1–2 mm. broad	
From the bottom	76,	59,	44,	30,	20

The mean rate of increase of mottling is 1 mm. in 10 to 13 feet. There is an alteration at 370, epidote at 378 and 382.

Thickness 194 feet (188).

Ed 6 b 5, 425-577, clasolitic amygdaloid. The rest of the hole is occupied by fine grained trap or amygdaloid with numerous small streaks and seams of red shale or sandstone often showing the dip.

The dip against the drill cores is as follows:

At 443 ft. 1 or 2 :8, 1½:8 (83°, 76°, 78°) ave. 79.
464 3¼:8, (67° 50′)
475 2½:8, 72° 40′ indurated white sandstone.

511 6 or 7 :8, 59°
Average 69° 22′

This would mean a dip of 61° for the strata. There appear to be some pebbles at 463 feet and at 495 feet, 498, and 501 there is much indurated sandstone. The question whether there is a broad belt of scoriaceous conglomerate (there appear to be pebbles at 467) or a series of small flows, or whether the drill hole may not have accidentally struck into and followed a clasolitic seam is not easy to determine. I incline to the last supposition. It resembles in many ways Ed 4 b 3.

Thickness 152 (149) feet.

§ 21. WYANDOTTE MINING COMPANY. (PL. XII.)

Next southwest to the Elm River were the explorations of the Wyandotte company, about two miles away on Sections 28, 21 and 16, T. 52 N., R. 36 W.

Here, too, a complete section has been made by drilling from the eastern sandstone in Holes 13 and 14 and the cross-cut in the south part of Section 28 to the shaft on Section 16 above the Shawmut conglomerate and perhaps nearly up the horizon of the Pewabic lode. The section of the upper part is given by natural exposures shown in Plate XII. The following are notes on the drill cores. The record is largely from data furnished by F. Van Orden (agent). There has been much cross-cutting since.

Geological Cross-Section of Wyandotte Property.

Wyandotte drill hole 1. 1100 feet N. and 700 feet W. of the S. W. cor. of Sec. 21, i. e., S. E. of Sec. 20. Dip 40° ends in Winona lode?

Only a small part of the cores was saved. The dip of the beds is about 70°. Hence the true thickness is obtained by multiplying by sin 70°=.94 while the horizontal width is about that in the hole.

Box 1 is all ophite. Box 2 is in part amygdaloid, then feldspathic melaphyre. Box 3 shows a scoriaceous amygdaloid, then a fine grained ophite.

The record by F. Van Orden is as follows:

	Thickness.	Horizontal width.
Standpipe ("overburden" of surface deposits)	118.5 (102)	118.5
Amygdaloid, vein and ore		
Vein trap		
Amygdaloid vein trap } horizon of Winona lode?		
Epidote		
Coarse trap (probably ophite)		
Vein trap		
Vein		
Vein trap		
Coarse trap		
Melaphyre sandstone (i e., basic red sandstone. Cf. 7.166 and 5.138)		
Conglomerate		
Vein		

		Thickness.	Horizontal width.
563′ 7″ in rock		(530)	563′ 7″

Hole 2 should be geologically above 1. The two are supposed to make a continuous section and show the absence of any conspicuous sandstone or conglomerate for several hundred feet above the Winona conglomerate No. 8. This is also true in the Arcadian section, and at the Elm River and helps in the broad identification.

Wyandotte drill hole 2. 1475 feet N., 900 feet W. of the S. W. cor. of Sec. 21, the S. E. of Sec. 20.

The dip of the hole is 40°. Assuming the dip of the beds to be 70°, the true thickness is obtained by multiplying by sin 70°, while the horizontal width is about that in the hole.

The record is:

Standpipe	88′ 2″	(83)	88′ 2″
Coarse trap			
Soft "			
Coarse "			
Soft "			
Coarse "			
Soft " The above probably one ophite belt=Win. d. 10. 244-428			
Amygdaloid			
Amygdaloid vein trap Cf. Win. d. 10. 428-472			
Amygdaloid Cf. Win. 10. 484-end			
Coarse trap			
Amygdaloid			
Soft trap			
Amygdaloid			
Soft trap			
Coarse trap			
Soft trap			
Coarse trap			
Soft trap			
Amygdaloid Winona lode ?			
Soft trap			
Total in rock	448′ 4″	(421)	448′ 4″

Wyandotte drill hole 3. 487 feet S. and 1600 feet E. of center in Sec. 21. From this point two holes were put down; one at a dip of 40°, 204 feet to rock, then the second at 70°, 159 feet to rock. Supposing the strata dip 60°, we have the same factors as for Hole No. 4. For true thickness multiply by .766 and for width by .884. The cores were not legibly marked and for distances I depend on F. Van Orden. Both Holes 3 and 4 show well-marked and good sized ophites.

Overburden 159

Scoriaceous conglomerate d 3. 202

Ophite d 3. 202?-279

Thickness. Horizontal width.

Scoriaceous amygdaloid (or conglomerate) top brecciated black and white, with red clasolitic veins, and at d 3. 202-208 an epidotic amygdaloid, then coarser; at d 3. 248 the augite mottles are 2-3 mm. across. Cf. No. 4, 9.

Melaphyre d 3. 279-311 32 (20) 28

At d 3. 268 1-2 mm.

Largely amygdaloidal at d 3. 304 feet more compact.

Ophite d 3. 311-520 209 (160) 184

Amygdaloid to d 3. 311

Mottles at 336 are 2 mm.; at 374 are 3-4 mm.; at 420, 75′ from bottom; 1-2 mm. at 503.

Is this the first flow of d 4. 349?

Ophite d 3. 520-574 54 (42) 47

Amygdaloid nearly to d 3. 535. Mottles 2 mm. across at 545 (22 feet above the bottom).

Amygdaloidal melaphyre d 3. 574-600 24 (18) 21

Perhaps a gush of the underlying, (rest of 60 vein amygdaloid).

Ophite d 3. 600?-659+(40+)? 99+ (?85+) 88

Amygdaloid to d 3. 574 finishing in a coarse ophite with 3 mm. augite mottles at 659. (Van Orden 47 ft. trap and part of 60 ft. overlying amygdaloid).

Wyandotte drill hole 4. 825′ S., 1475′ E. of the center of Sec. 21, T. 52, R. 36, at an angle of 70°. It is near Mich. Geol. Surv. B. M. 40 which is 640.58 above Lake Superior, about 1200 ft. A. T. Being composed of heavy ophites with little or no conglomerates, it reminds one of the beds in St. Mary's drill holes Nos. 3 and 5, and the Elm River drill holes 4 and 5, and Belts 132-144 of the Arcadian section, and Win. d. 12. A hole at an angle of 40° west 316 feet without striking bed rock.

The hole gives no clear indication of the dip of the beds. Supposing it to be 60° the true thickness must be found by multiplying by sin 130°=.766, and the width by sin 130° sin 60°=.884

Overburden 193 170

Ophite d 4. 193-4.349 (50+) 156+ (170+) 196+

This is evidently struck in the middle of a large flow as the augite mottles are 4 mm. at the beginning, at d 4. 268 they are 4-5 mm. (62′ from bottom). It is somewhat seamed and fissured and *coarsely* amygdaloid at 298 and 311.

Amygdaloidal melaphyre d 4. 349-372 23 (18) 20

A well-marked white and gray amygdaloid for the first 5 feet, and chloritic amygdaloid to d 4. 361. Possibly a gush of the underlying flow.

Ophite d 4. 372-538 166 (119) 147

A marked green and white amygdaloid for 9 feet, at about d 4. 451 coarsest (4 mm? at 65′ from the bottom).

Amygdaloidal melaphyre d 4. 538-574 36 (28)

A gray and white amygdaloid, finer at the bottom.

Ophite d 4. 574-721 (+10 or 20 feet) 147+ 130

At top 6 feet of marked red and white amygdaloid, at d 4. 643 feet 3 mm. patches seamed, at 675, 4-5 mm. patches, (at 35+20 from the bottom), at 721 down to 1-2 mm.

Thickness. Horizontal width.

Wyandotte drill hole 5. 1450′ N. and 1600′ E. of the center of Sec. 21, T. 52 N., R. 36 W. at an angle of 60°. The dip from the drill cores appears to be about 60°. Hence the true thickness is found by multiplying by sin 120=.87.

Overburden 54.7 54.7

Feldspathic ophite d 5. 11-138 127 (118+) 127+

The top for 12 feet is fine grained and amygdaloid so we must have nearly the whole of this flow. At d 5. 34 the augite mottles show 1-2 mm.; at d 5. 87 they are 2 mm. At d 5. 90-98 are laumontitic seams. From d 5. 125 to 138 it gets plainly finer and amygdaloid.

Dark shale and scoriaceous conglomerate d 5. 138-169 31 (29) 31

From d 5. 138-144 it is like a scoriaceous amygdaloid and may be considered a mixture of the overlying flow with the red mud. Then there is a dark chocolate indurated shale, then red shale with a well-marked dip (56.5° to 62.5°) with a few inches of basic and scoriaceous debris only at the bottom. Cf. d 7. 166-200.

Amygdaloidal melaphyre d 5. 169-234 65 (60) 65

This is not clearly defined and may include more than one flow for close beneath d 5. 169 it is a feldspathic coarse amygdaloid, then from d 5. 175 on, finer and markedly amygdaloidal to d 5. 182, then more compact and feldspathic, beginning to be sparsely amygdaloid again at d 5. 228 feet.

Amygdaloidal melaphyre d 5. 234-297 63 (58) 63

For 5 feet it is a well-marked amygdaloid, but then more compact though near d 5. 245 it is coarsely amygdaloid and laumontitic, also at d 5. 264, while at d 5. 274 it appears more compact and at d 5. 275 very much altered,—a contact of a new flow or a slide fault is quite possible. Cf. shaft A at Elm River. It is slightly amygdaloid at d 5. 282.

Amygdaloïdal melaphyre? d 5. 297-307 10 (9) 10

Sandstone altered, epidotic (copper) d 5. 307-314 7 (6) 7

Cf. d 7. 285-295

Sp. 20358 is from Wyandotte d 5 at 307 feet. A section was made to see if the sedimentary structure was brought out more plainly. It is composed of granules mainly less than 0.21 mm. up to 0.36 mm. They are of quartz, epidote and feldspar. Calcite also occurs and shows pressure twinning. There is a quartz vein faulted normally by other slips and a quartz seam has a yellow calcite on one side, apparently later. The whole bed is full of veins with little faults and is much shattered. Its sedimentary structure is not plain.

Amygdaloid, melaphyres d 5. 314-340 26 (24) 26

Scoriaceous amygdaloid at top and the epidotic seam I have classed as sandstone and belongs mainly to it.

Conglomerate d 5. 340-349 9 (8+) 9+

Rather basic though with many felsite pebbles.

Cf. d 7. 361 with d 5. 340 and Elm River Hole 3.

Total 349+55=404 404

I strongly suspect a slide fault disturbing the records, making them different at different places and altering the beds at about d 5. 275.

Thickness Horizontal width.

Wyandotte drill hole 6. 1500′ E. and 700′ N. of the center of Sec. 21, T. 52 N., R. 36 W, 170′ S. E. of the No. 2 shaft, is at an angle of 60°. The dip from the drill cores appears to be 67°±4°. Hence the true thickness is found by multiplying by the sin 127°=.8, the horizontal breadth by sin 127° sin 67°=.87.

The hole begins in a conglomerate and ends in one. The upper may be No. 7, the lower No. 6. Both of them outcrop, from the outcrop the strike is N. 53° E, not as at the Winona N. 59° 30′ E. The holes were probably not quite inclined at right angles to the strike but it would make no appreciable difference in the estimated true thickness.

	Thickness		Horizontal width.
Conglomerate d 6. 0-21 (No. 6?)	21	(17)	19
Melaphyre d 6. 21-47	26	(21)	23

This thin flow is markedly amygdaloid (black and white) almost all the way to d 6. 41

Sandstone and conglomerate d 6. 47-6.62	15	(12)	14

This is brown (not red) for the first 4 or 5 feet. The dip, from the inclination of its banding to the drill cores, is between 62° and 72°. Then there is a white band (deoxidized), then basic pebbles appear and it passes from a scoriaceous conglomerate to a scoriaceous amygdaloid. Cf. Elm River d 4. 258-315 and d 3. 328-353.

Ophite d 6. 62-135	73	(58)	63

This begins with a marked scoriaceous amygdaloid, at 78 feet very epidotic, with clasolitic seams making it hard to decide where the conglomerate ends. At 127′ 7″ a brecciated red and green chloritic fault zone may be crossed.

Conglomerate d 6. 135-173. This is said to be 200 feet wide at Elm River (Ed 4 b 2 ? or Ed 1 b 1 ?)

Wyandotte drill hole 7. 362′ E. and 710′ N. of center of Sec. 21, T. 52 N., R. 36 W., at an angle of 40°. The dip from the drill cores appears to be 60° 40′. Hence to reduce the thickness one should multiply by the sin 100° 40′=.983. To reduce to horizontal breadth one must multiply by sin 100° 40′ sin 60° 40′=.983÷.872=1.124. The uncertainty as to dip affects the second figure, and makes computations more accurate than 3 places or than a slide rule can give useless.

The record from the samples is as follows (with aid of F. Van Orden's notes) beginning just below the foot of a conglomerate No. 8?

Overburden, Quaternary	29	(29)	33
Feldspathic doleritic melaphyre d 7. 1-48 beginning just at the verge of the amygdaloid top with a band or spot epidotic with copper at d 7. 28 feet.	48	(47)	55
Ophite d 7. 48-166	122	(118)	139

There is a well-marked brecciated amygdaloid with calcareous cement for 48-77 29 feet, then mottled at 104, to 128, 137-157 (fissured) patches 2 mm., 3-4 mm., and 1-2 mm. respectively.

Red shale d 7. 166-200, dip (on drill cores 10° 40′) 60° 40′	34	(33)	39

The last 8 feet are somewhat uncertain. F. V. O. connected them with the bed below.

	Thickness		Horizontal width.
Melaphyre d 7. 200-264?	64	(63)	72

This bed is at the top a fine grained feldspathic trap, with seams of the overlying red shale filtered down as clasolites into its cracks. The amygdaloid has perhaps been eroded away, or cut off by a slide. It is laumontitic and veined with calcite at 230, 237, 253 and epidote at 254.

Melaphyre, amygdaloid, lower or preliminary gush of flow above? d 7. 264-285	21	(21)	24
Scoriaceous conglomerate passing into brecciated amygdaloid d 7. 285-295	10	(10)	13
Ophite d 7. 295-361	66	(65)	74

The augite patches are 2-3 mm. across at d 7. 315.

The base below d 7. 345 is fine grained and blue-black.

Conglomerate d 7. 361-364′ 10″. This may be Conglomerate 7	4+	(4+)	4+
Total 364 feet 10 inches+29=394		(384)	445

Wyandotte drill hole 8. (No cores in a vein; in a trap a little of the conglomerate. Cores are mislabelled 9). 825′ N. and 800′ E. of the center of Sec. 21, T. 52, R. 36.

3-30 ophite, mottles 2-3 mm. across, at 39 veined, at 40 coarsest, at 64 growing finer, at 96-99 altered, at 101 still a fine grained ophite, at 116 brecciated, at 119 clasolite, and from 131 on all dark, brecciated, fine grained stuff with calcite matrix -194, with streaks of epidote. It continues down in this belt all the way, alternating fine grained trap breccia and amygdaloid, and clasolitic seams of red sediment as follows:

Clasolitic at 235, 300;

Trap at 240, 253, 279;

Amygdaloid at 245, 281, 349, 361;

Breccia at 260, 262, 282, 292;

Toward the very end at 370-379 the hole seems to be passing into a feldspathic trap such as is common in the upper parts of flows.

(No copper was mentioned).

Wyandotte drill hole 9.[1] 275′ S. and 372′ W. of the N. ¼ post of Sec. 28, T. 52, R. 36, dipping to S. 37° E., at an angle of 55°. The dip on the red shale appears to be 56° or so. Hence for the true thickness multiply by sin 69°=.93; for the horizontal width multiply by sin 69°/sin 56°=1.12

Overburden	269′ 7″	(251)	302
Conglomerate and shale d 9. 1-9.80	80	(75)	90

Brown and gray calcareous sandstone at d 9. 62-78, red shale d 9. 78-80, dip in the drill core respectively 23.5° and 21°.

Amygdaloid conglomerate (and amygdaloid?) d 9. 80-114	34	(32)	38

Apparently just below d 9. 80 it is a well-marked, black and white amygdaloid with clasolitic seams, which may be merely the top of the underlying ophite or may be a bouldery lower part of the bed above.

[1]Another hole had its boxes also labelled 9, wrongly F. V. O.

Thickness. Horizontal width.

Cf. Win. d. 13 which appears to have a similar phenomenon, also the C. & H. in the Franklin Jr. cross-cut.

Ophite d 9. 114-231 — 117 (109) 131

At d 9. 202 the mottles reach 3 mm; at 9. 191 it is epidotic. Cf. 10. 374.

Amygdaloidal melaphyre d 9. 231-307 — 76 (71) (85)

A black and white amygdaloid rather coarse to 246, seamed and partly amygdaloid to 279, and fissured at 291, compact at 294.

Cf. d 10. 368-426.

Ophite d 9. 307-430 — 117 (109) 131

Amygdaloid to 319. The top contact is not well marked.

Seams at 324, 328, 331, 360 nearly perpendicular to the hole, 374, 378. At d 9. 352 3 mm. mottles and coarse to d 9. 407.

Amygdaloidal melaphyre d 9. 430-502 — 72 (67) 81

To d 9. 460 it is brecciated and scoriaceous, and it is much veined.

Ophite d 9. 502-552 — 50 (47) 56

A black and white amygdaloid to d 9. 516, and at 530 mottles 2-3 mm. across, then brecciated and amygdaloid at the bottom.

Ophite d 9. 552-587 or 624+ — 72? (67) 81+

It begins with a well-marked red and white amygdaloid but passes at 587 into an epidotic band indurated and altered and ends in a fine grained ophite.

Wyandotte drill hole 10. 250′ N. of line and 500′ E. of S. ¼ post Sec. 21, T. 52, R. 36, dip at an angle of 55° to the S. 37° E. The strata appear to dip 56°. Hence for the true thickness multiply by sin 69°=.93, and for horizontal width by sin 69°/sin 56°=1.12. It is 290 feet along the strike and 290 in the direction from the dip, i. e., S 37° E? from No. 9. This does not agree with above statement.

Overburden, standpipe — 253 (242) 283

Ophite d 10. 1-39 (or 17?) — 39 (36) 44

Only the base of this flow is seen and at d 10. 3 it is 1-2 mm. There may be any amount more of it.

Ophite d 10. 39-156 — 117 (109) 130½

Begins as a marked black and white amygdaloid to d 10. 49, at d 10. 75 is brecciated, at 89 and 110-116, 118, 131, 143-148, it is veined, the mottling is 2 mm. across at 83-89, and at 137 is 1-2 mm., and is brecciated down to the foot.

Conglomerate and sandstone d 10. 156-252 — 96 (89) 108

From d 10. 238 down it is sandstone with good chances to observe dips against the core,—of 14°, 21°, 21°. — 25 23

Scoriaceous amygdaloid or conglomerate d 10. 252-277

Cf. d 9. 80. A marked black and white amygdaloid with clasolites? or in part conglomerate.

Ophite d 10. 277-368 — 91 (85) (102)

Cf. d 9. 114-231. Mottles 2-3 mm. across at d 10. 348, 1-2 mm. at 329, veined at d 10. 355.

Amygdaloid d 10. 368-395 — $\frac{27}{118}$ $\frac{(25)}{110}$ $\frac{60}{162}$

At d 10. 374 light yellow altered, at d 10. 395 fine grained red. This is probably the true bottom of the flow, the amygdaloid above being a skeining or preliminary gush.

	Thickness.		Horizontal width.
Faulted zone or scoriaceous conglomerate d 10. 395-426	31	(29)	69

Part of this all belongs with the belt below, but it is much decomposed d 10. 405, brecciated d 10. 411, and seamed d 10. 419, with calcite d 10. 414, and the correspondence with Hole 9 breaks off.

Ophite d 10. 426-491	65	(60)	73

The top of this is represented in the belt above, for at d 10. 435 the mottles are 2-3 mm. across, the rock is still much veined, at 477 the mottles are 3 mm. across, then finer.

Ophite d 10. 491-557	66+	(61+55+)	130+?

Amygdaloid to 496. Mottles 1-2 mm. at 520 and at 557 coarse 4 mm., so there may be any amount more of it.

The top of this hole resembles very strongly for a ways the beds in No. 9. This would give a strike of N. 59° E., which is close to that at the Winona lode. But correlating d 9. 80 with d 10. 252, if the holes are on a level would give a more easterly strike. I think it is safe to correlate d 9. 80 with d 10. 252, and a correlation may be made out as far as the fault zone d 10. 395-426, which seems most nearly to correspond to d 9. 430 to d 9. 460 which has, however, different surroundings. It may be that the same shear zone passes through the holes at different levels.

Wyandotte drill hole 11. Said to be 285′ in direction of (thickness) the section from No. 10 in Sec. 21 or 28, T. 52, R. 36, at an angle of 55°. Hence assuming that the dip is 56° for the true thickness, we multiply by sin 69°=.93, for the horizontal width by sin 69°/sin 56°=1.12.

Overburden (standpipe)	218		245
Ophite d 11. 1 to 117	117+	(109)	131

There are amygdaloid enclosures. The mottles are 2-3 mm. at d 11. 44, and it is coarse from d 11. 68-91. It can not be much thicker. Should correspond to d 10. 277-395.

Ophite d 11. 117-363	246	(228)	275

It is amygdaloid from d 11. 117 to 124 and scoriaceous or a fault breccia at 129, 134, 139-141, succeeded by a fine grained black trap and the coarser mottles 2-3 mm. do not appear until d 11. 151. I judge there is slide faulting along the scoriaceous top of the ophite. It is brecciated again at d 11. 160-166 and seamed between d 11. 194 and 208. The mottles are 2-3 mm. across at d 11. 189 and 215. It is more seamed at d 11. 221. At d 11. 232 the mottles are 3 mm. across, at d 11. 289 4-5 mm., at d 11. 331 2-3 mm., at d 11. 338 it is somewhat amygdaloid. The grain and brecciation indicates that the top of the belt is much faulted. The only thing this can correspond to in No. 10 is d 10. 491-557 which is as coarse.

Conglomerate d 11. 363-367	4+	(4+)	$4\frac{1}{2}$

Cf. Win. d 11. 460. Cf. Wy. d 9. 1 and Wyd. d 10. 156.

If that is the case d 10. 557=d 11. 289 about,—a difference of 288 feet. The beds above can not be closely correlated since the fault comes in. The beds in No. 11 should be struck if the dip is only 56°, about 255 feet sooner than in No. 10. Cf. the big ophite in Winona drill hole No. 11.

Wyandotte drill hole 12. 88′ E., 525′ N. of the W. ¼ post of Sec. 28, T. 52, R. 36. Dip of hole 55°, 131 feet standpipe, 626′ 7″ in rock. Total 757′ 8″. If the dip of

				Thickness.	Horizontal width.

the strata is 70°, the true thickness is obtained by multiplying by sin 125°=.819 and the horizontal breadth by sin 55°/sin 70°=.87.

Overburden ·	131		width	114
Melaphyre, fine grained amygdaloidal d 12. 1-25	24	(20)		21

Van Orden trap 22.5 ft.

Sheared amygdaloidal melaphyre or scoriaceous top of ophite perhaps including a sedimentary horizon.

Cf. Baltic lode d 12. 25-39 light yellow epidotized, also at 59, and amygdaloid brecciated at d 12. 71. At d 12. 73 the augite mottles are 2 mm. across.

d 12. 25-86	61	(50)	53

This and the follpwing are divided by Van Orden as 28.7 amygdaloid, and 143.2 trap.

Ophite d 12. 86-202	116	(95)	101

Much sheared with epidote top to 93, at d 12. 124 the augite mottles are 2 mm. across. From 190 down it is light colored, altered.

Amygdaloidal melaphyres d 12. 202-264	62	(51)	54

Part of this probably belongs with the flow but the strata are much disturbed and it is hard to make out the belts. Van Orden divides this and the following as 9′ 2″ quartz and calcite, and 234′ 3″ trap.

Ophite d 12. 264-437	173	(142)	150

Decayed and decomposed.

Conglomerate and sandstone d 12. 437-530	93	(76)	81

The bottom 9 feet are sandstone apparently. Unless there is a fault this is lower than any conglomerate in the Winona section, i. e., it must be No. 3, the Baltic conglomerate or lower.

Amygdaloidal melaphyre d 12. 530-626.7	96.7	(89)	84

The samples as found were largely amygdaloid but Van Orden divides it into 44 feet amygdaloid and 55′ 3″ trap. The hole is probably near some disturbance, either a slide fault or a cross-fault. It is pretty near the Eastern sandstone and the great Keweenawan fault.

Wyandotte drill hole 13. 213′ E. of the ⅛ post on the S. line of Sec. 28, T. 52, R. 36.

Overburden	(196) feet.
Eastern sandstone	(400)

There is very little core, not more than 2 boxes, say 50 feet from the whole 400. The bedding is at nearly 45° to the core (36° 40′ to 41° 20′) which indicates that the bedding is either about horizontal or about vertical. I presume in this core it is nearly horizontal dipping between 1° 40′ and 6° to the N. W. Much of the sandstone is white, loose grained and sugary, but it is also red and white banded and spotted.

Sp. 20356 is of the eastern sandstone, from this hole. About 50% of it is quartz. Orthoclase is about 30%, microcline with distinct twinning net-work about 10%, and there is plagioclase and a micaceous cement, perhaps not more than 10% of the whole mass. Biotite occurs. There is one grain of pleochroic tourmaline. There is, I should judge, not over 1% of iron oxide and there appear to be 1 or 2 grains of felsite ground mass with a trichitic arrangement of the feldspars.

Wyandotte drill hole 14. 50′ E. of the ⅛ line and 565′ N. of the S. line of Sec. 28, T. 52, R. 36.

Overburden (160)

Eastern sandstone (406)

There was so much water in it that the sandstone fretted away and had to be cemented before boring, it was so friable. The grains were rather coarse (2 mm. or so). The dip against the drill core was (5:8) 32° and the true dip perhaps 3°, practically horizontal.

Wyandotte drill hole 15. 910′ N. and 392′ W.

Overburden (185)

Sand, gravel and boulders,—no rock.

Wyandotte drill hole 16. 8′ S. of the ⅛ line and 637′ E. of the W. line of Sec. 28, T. 52, R. 36.

Overburden (199)

Eastern sandstone (100)

Soft, red (and spotted white) sandstone, largely came up as sand.

Wyandotte drill hole 17. Abandoned.

Overburden (60)

Wyandotte drill hole 18. 488′ S. of W. ¼ post, and 87′ E. of W. line of Sec. 28, T. 52, R. 36.

This is near the shaft from which drifts are run which is 450′ S. of the W. ¼ post and 175′ E. in Sec. 28, T. 52, R. 36. Just a short way in. Cf. record of shaft and drifts.

Wyandotte drill hole 19. 475′ S. E. of No. 6, on a line perpendicular to the strike. Dip 55°. Hence if the dip is 67°, the true thickness will be found by multiplying by sin 122°=.848 and the horizontal width by (sin 122°/sin 67°)=.91.

	Thickness.		Horizontal width.
Overburden	128	(109)	116
Ophite d 19. 1 to 253	253	(214)	230
This is struck near the top and is at the beginning amygdaloid. The augite mottles grow coarser down to about d 12. 188 feet (55 feet above the bottom) where they are 5 mm. across, at d 12. 193, (50 feet), 4 mm. across and then finer.			
Ophite d 19. 253-320	67	(57)	61
Amygdaloid for 2 feet, then from 265-270, an epidote streak or inclusion, also at 289-296, and at 311.			
Fault ? at d 19. 320			
The rock is brecciated and no well-marked amygdaloid separates the two ophites.			
Ophite d 19. 320-390	70	(59)	64
The augite mottles are at 343 2-3 mm., growing coarser, at 359 (26) 3 mm., at 371 (18) 2-3 mm., at 378 (11) 1-2 mm. The last 4 feet 386-390 are amygdaloid.			
Conglomeritic sandstone d 19. 390-400	10	(8)	9

§ 22. WINONA MINE (Pl. XII, Fig. 50).[1]

The next section, that at the Winona mine, is extra complete, and may be taken as a sort of standard, as the cores are preserved in the survey office, thanks to Dr. Hubbard, and the drilling was done under the supervision of F. W. Denton, the holes connected with adjacent outcrops, and a careful section prepared by R. T. Mason upon which Figure 50 is based. I have also examined the cores and made supplementary observations.[2] This is the first section below that at Calumet where a section can be made out from the Great (Copper Harbor) conglomerate down to and including much of the Bohemian Range group, in all 9,000 feet or so only, indicating a very considerable shrinkage in the traps, which appears to be largely in the upper part. On the other hand the conglomerates are as heavy and heavier than farther north.

GEOLOGICAL SECTION AT WINONA MINE.

ABSTRACT.

Conglomerate		980
Alternating conglomerate and ashbed trap to Island mine conglomerate? Above drill hole covered! Dip 52° d 1.	230–750	Sum.
Ashbed type Holes 1, 2, to d 3.131-213 (80.5) (Pewabic or Hancock W)	(580)	(1330)
From base of conglomerate d 3. 213 to base of conglomerate d 4. 581+ (60), Dip 56°¼	(825)	(2155)
From base of conglomerate d 4. 581+ (60) to base of d 6. 452+ (74), Dip 57.5°	(1517)	(3672)
From base of conglomerate d 4. 581+ to base of possible Allouez exposed in trenches	(117)	
First big trap and some pretty heavy beds and faults between	(129)	
From base of conglomerate d 4. 581+63 to base of d 5. 213 conglomerate	(737′)	
From base of conglomerate—d 4. 581+ (60) to base of d 5. 440 (first ophite noted by Mason) d 5. 208-213 is a *conglomerate and* sandstone.	(963)	
From base of conglomerate d 6. 452 (Johnson Creek or Shawmut) to base of d 7. 148-166	(128)	(3800)
base of d 4. 581 to base of d 7. 148-168 (1645)		
From base of conglomerate d 7. 166 to base of d 8. 232-282. Dip 66°	(397)	(4197)
base of conglomerate d 3. 213 to d 8. 282 is (2867)		

[1] Plate XII and Fig. 50 are in envelope.
[2] Separated from the earlier notes by a double dash.

From base of conglomerate d 8. 282 to base of d 9. 88+ (=d 8. 590, d 8. 450 between) sandstone, dip 70°	(321)	(4518)
From base of d 9. 88 to base of d 9. 217 (The Wolverine No. 9)	(123)	(4641)

Discussion of correlations here.

From base of d 9. 217 to hanging of Winona dip about 70°	(1090)	(5731)
From hanging of Winona to base of Winona conglomerate (8) about	(493)	(6224)
From hanging of Winona to base of conglomerate 6 (acid)	(575)	(6799)
From base of conglomerate 6 to base of Winona d 13. 62	(632)	(7431)
From base of d 13. 62 to base of Winona d 11. 168 (3 big ophites?)	(613)	(8044)
From base of d 11. 168 to base of Winona d 11. 544 (Fault repetition?)	(362)	(8406)
From base of d 11. 544 to base of Winona 12 and end of section all ophites	(602)	(9008)

Winona Cross-section.

In this section the following conventions are used. Annotations or additions by the geologist to the engineer's record are separated by a dash repeated thus. (- -)

The word thickness refers to the thickness at right angles to the dip and the strike; the word width to the horizontal width, which is formed by multiplying the thickness by the cosecant of the dip. The word depth refers either to distance along the drill hole or down a shaft. The thickness is derived from the distance along a drill hole by multiplying by the sine of the sum of the angles of dip of the drill hole and of the strata, since the drill holes are inclined practically at right angles to the strike. Figures referring to thickness are enclosed in parenthesis. Figures referring not to an immediate belt but to totals for several belts when occurring in the course of the column have a line above them, and are taken usually from tops of amygdaloid to top of amygdaloid, which are much better defined than their foots, and from base of conglomerate to base of conglomerate, since the bases of conglomerates have usually been used to figure from, though their hanging walls are often better defined and are really in many cases slide planes.

Reference to other sections are abbreviated as follows:

Winona drill hole No. 1 at 355 feet from the surface to Win. d 1. 355, etc.

Tamarack No. 5 shaft, engineers belt 6 to T 5 b 6, etc.

Tamarack No. 5 shaft, my division into flows and beds in the Annual for 1903, p. 253 et seq. to T 5 f.

Elm River drill hole to E. d

Wyandotte drill hole to Wy. d

Arcadian drill hole to Arc. d

Calumet & Hecla to Cal.

The elevations are referred to sea level by way of the Bench Marks of the Ontonagon road survey.

There are some indications of a flattening dip from the south to the north end of the sections. Mason notes with pencil a dip of 52° for Hole 3. A correlation of the bottom of Hole 4 gives 56°¼. From outcrops in Sec. 19 a dip of 55° was obtained. The dip on the Winona lode is 70° at the beginning, 68° average.

In putting in the belts on Fig. 50 the draftsman used a uniform dip of 65° but

that does not seem strictly accurate. I have accordingly computed the dips and thicknesses for each part of the section independently, using the slide rule, and such dips as seemed probable, with due regard to correlations, etc.

The direction of the dip of the drill holes was intended to be that of the section, at right angles to the strike of the formation or the Winona lode N. 59° E. In getting the standpipe in place a little shifting would occur, and I have given the actual directions. These differ, however, not over 3° from N. 31° W., the direction of the section, and would not affect the thickness a tenth of a per cent, being entirely inappreciable in individual belts, and much less than the probable errors introduced by faults, unknown veering in the course of the drill holes and other sources.

The section above drill hole 1 may be completed somewhat by outcrops, especially a section on a stream in Sec. 24, T. 52 N., R. 37 W. See map. (Plate XII.)

Nothing but conglomerate has been found above this section—say 1200 feet above drill hole 1 say in thickness *above* (980) feet.
This perhaps outcrops near the E. Q. P. of 24 and a conglomerate is exposed in Sec. 33, T. 52, R. 37 which may be the Great conglomerate.

3.	Melaphyre (trap succeeds for 114 paces or is covered). There *may* be more than one flow.	(49)	60
4.	Amygdaloid and trap.	(38)	47
	Forbes compared the amygdaloid with one at the top of the section on Sec. 16, T. 52, R. 36; the contact with the underlying conglomerate strikes N. 60° E., and dips 55°.		
5.	Conglomerate dip 55° to N. 30° W?	(12)	width 15 ft.
6.	Porphyrite, fine grained trap of Ashbed type.	(58)	71
7.	Conglomerate	(17)	21
8.	Melaphyre	(30)	37
9.	Conglomerate	(17)	21
10.	Melaphyre porphyrite	(10+)	13+
	An agatiferous amygdaloid passing to south down into a fine grained feldspathic trap. The elevation at the S. E. end of the section is about 1170 A. T.		
	Total perhaps	(231)	285
	End of section above drill hole 1 say	(750)	

An outcrop of conglomerate and trap 440 paces S. 1200 W. of the N. E. corner of Sec. 19, T. 52 N., R. 36 W., appears to correspond to the lowest conglomerate and trap of this section. The consequent strike is N. 59° E. like the Winona lode.

No exposures of the section between the end of this section and the top of the Win. d 1 appear nearer than possibly Sec. 10, T. 52, R. 36, but it is not far above Win. d 1.

This section appears to belong to that upper part of the Keweenawan series where the volcanic activity was dying out and traps frequent, just below the Great Conglomerate. This is the Eagle River group, Gordon's Division VI of the Black River Column, the first thousand feet of the Eagle River section, Marvine's Group (c), the top of the Tamarack 5 shaft above T 5 b 7 and westward, and on Isle Royale the part above the Island mine conglomerate. Below T 5 b 7 there are some 2000 feet of beds of sodic and feldspathic type which I have called melaphyre porphyrite. We are not surprised therefore that the beds in Win. d 1 are of the melaphyre porphyrite type, and that the first ophite, noted by Mason as such is (2000) feet lower.

Winona drill hole 1. 1265′ .7 feet A. T.; 520′ N., 2440[1] W. of E. Q. P. Sec. 19, T. 52, R. 36. Dip of hole 40° toward S. 28° 51′ E. Dip of beds 52°. Hence for true thickness multiply distances on hole by sin 92° = .9994, for horizontal widths by sin 92° sin 52°=1 ÷ .788=1.27

Surface deposits (collar to rock) 25 (25)

11. Feldspathic melaphyre – – mainly brown trap
d 1. 25 to 62 – – 37 (37) (47)
– – the feldspar is 1-2 mm. long but not really a typical ashbed melaphyre.

12. Melaphyre porphyrite, fine grained, reminding one of a felsite.
– – Brown amygdaloid with calcite 62-69, brown trap –73, brown amygdaloid with calcite epidote chlorite – 79, brown trap – 103
– – d 1. 62 – 99 37 (37) (47)

13. Melaphyre porphyrite d 1. 99 – 140 41 (41) (52)
From d 1. 99 – 103 is a marked red calcareous amygdaloid, and below is a fine grained black trap like the Minong trap.

14. Melaphyre porphyrite d 1. 140 – 189+ + + +.
A red amygdaloid passing at d 1. 152 – 153 into a white brecciated amygdaloid with indurated sandstone seams, clasolites. It continues fine grained all the way to the end. – – From 232 to 282 feet along the line of section from No. 1 is a trench exposing trap – – which extends the last belt down from d 1. 189 equivalent to d 1. 230 making it 70 (70) (89)

This does not quite complete the section to Win. d. 2.

Winona drill hole 2. Collar 1261 A. T.,[1] 100 ft. N., 2400 ft. W. of E. Q. P. of Sec. 19, T. 52, R. 36.

This hole is 322 feet S. 31° E. from Hole 1 horizontally on the section or 254 ft. below. Dip as before 40° to S. 33° 22′ E. For true thickness multiply by .9996. (37.5) (42)

There is a gap of 24+13.5 feet.

Overburden d 2. 0-13.5

15. Trap d 2. 14 – 93 – – Glomeroporphyritic, not mottled, with some white amygdules at top (79) (100)
Amygdaloid d 2. 93 – – true trap – 116 (23) 28

16. Amygdaloid 5, weathered trap 18 – – the amygdaloid red with white and green concentric banded amygdules, the trap feldspathic.
Amygdaloid d 2. 116 – 126 and trap – 131 – – reddish feldspathic. Amygdaloid? – 132, compact green trap – 135 and trap – 143 – green and fine grained, or with characteristic specks (27) 34
Total from top of Win. d. 1 (397)
– – At the end it is near or at another amygdaloid.

Winona drill hole 3. 1265.8 A. T.
Dip of hole 39° to S. 32° 28′. At 52° dip (multiplying by sin 91°) there will be no appreciable reduction for true thickness. For width multiply by 1.27. This hole is 140 feet horizontally on the section from No. 2 which at a dip of 52° corresponds to a thickness of (109) feet
460 feet from Win. d 1 which corresponds to a total of (362) ft.
Surface deposits 28 feet.
Trap? d 3. 28–36 – – lapping perhaps 7 feet on the bottom of Win.

[1]Pit about 5 feet deep, then cemented standpipe to edge.

d 2. Well-marked contact at 42 with red amygdaloid below, gray trap above.

18. Amygdaloid d 3. 36 – 42 and trap – 65

Amygdaloid, greenish, compact d 3. 65-70 and trap with some amygdaloid – 120 – – at 50 is a hard spot and the epidotic amygdaloid at 65 is not a contact but there is one heavy feldspathic bed to 120.

19. Amygdaloid d 3. 120-126 and trap 131

20. *Conglomerate* d 3. 131-203 and sandstone – 212.84 (81.5)

Win. d 3. 131-212.84 very probably corresponds to T. 5 b 12 or to b 23. The former is assumed to be the *Hancock West* or Marvine's 17 conglomerate. The latter is the Pewabic West or Marvine's 16, not far above the Pewabic lode, at the Quincy mine (623) feet. Counting every conglomerate up from the one we take to be the Wolverine sandstone, Marvine's No. 9, would make this No. 18, and the loss of one number is far from surprising.

The beds are very typical glomeroporphyrites of the ashbed series.

Total from top of Win. d 1 is (362) + (213) at a dip of 52° (575) or allowing something for increase of dip, since the next hole Win. d 4. seems to have a dip of 56° instead of 52° (580)

21. Amygdaloid d 3. 212-218 and trap fine grained chloritic 262 (47)

– – to 239 a very fine grained trap, a porphyrite.

22. Amygdaloid d 3. 262-274 and trap coarse grained 296, (36)

23. Amygdaloid d 3. 296-300 – – with clasolitic seams and ashbed appearance. And trap-317, (21)

24. Amygdaloid d 3. 317-324 and trap 332, (15)

– – a contact at 316′ 8″, trap above very glomerophyritic.

25. Amygdaloid d 3. 332-338 and trap 344, (12)

26. Amygdaloid (some trap) d 3. 344-378 and trap 384, (40)

– – This is at 377, etc., distinctly glomerophyritic and like Sp. 16421.

Amygdaloid d 384-398 and trap 452, (68)

(819)

Belts where so much amygdaloid in proportion to trap is reported have often turned out to be glomeroporphyrites as these are. Cf. T. 5 b 28. This is probably about the horizon of the Pewabic lode.

Winona drill hole 4. 1253 A. T.

Dip of hole 38° to S. 24° 17′. Allowance (38° 08′ to S. 31° E.) factor for incorrect direction of dip of hole .993. This hole begins 464 feet horizontally on the section from No. 3, which should overlap it at Win. d 3. 395, and finishes in a conglomerate the upper contact of which is exposed in trenches, so that a dip of 56°¼ may be inferred. Hence for true thickness multiply by sin 94° and for horizontal width by sin 94° ÷ sin 56°¼=1 83 =1.206.

Surface deposits 34

[27]. Trap – – as at the bottom of Hole 3 ? d 4. 36-62 (28)

28. Amygdaloid d 4. 62-67 and trap -82.5 – – a well-marked porphyrite (20)

29. Amygdaloid d 4. 82.5-90 and trap -215. A seam at 96 feet, above which the trap is hard, brownish, striated. – – This trap is coarse, feldspathic, glomeroporphyritic somewhat, and chloritic. (132)

30. Amygdaloid d 4. 215-225 and trap 309. Amygdaloid highly mineralized. From 232-270 fine grained. From 308 to 309 with olivine. – – The trap at 294 is glomeroporphyritic. (94)

31. Amygdaloid d 4. 309-315 and trap 395 (86)
– – feldspathic. At d 4. 367 coarse, olivine and augite showing. At d 4. 389 to 395 broken, seamy, finer grained.

32. Amygdaloid d 4. 395-406 and trap 424 (30)
. Greenish amygdaloid, with quartz and other minerals. This is probably a bomb and not a contact. Trap appears coarse grained.
– – Feldspathic and glomeroporphyritic.

33. Amygdaloid d 4. 424-435 and trap 476 (56)
Copper and calcite in green amygdaloid. – – Not very amygdaloid, more pseudoamygdules and porphyritic feldspar. At d 4. 434 passes into a hard amygdaloid, and at d 4. 435 from this to a coarse grained trap.

34. Amygdaloid d 4. 476-484-a genuine contact and fine grained gray and white Am., and feldspathic trap -534 (56)
At d 4. 460 are indications of slipping. At d 4. 470 it is fine grained.
At d 4. 477 the amygdaloid is very fine and hard. At d 4. 479 it is fine grained and soft and hard again at 482. The trap becomes fine at d 4. 530.

35. Amygdaloid d 4. 532-542 and trap -570 (48)
Calcite and copper in quartz in the amygdaloid, at 539 fine grained.
At 543 to 548 a porphyrite, – – at 551-2 coarse feldspathic.

36. Amygdaloid d 4. 570-574 and trap -581 (10)
The "amygdaloid" may be a vein.

37. *Conglomerate* d 4. 581 to 585+ (4)
Under the trap came a mud, perhaps a fluccan which made no core, and under this was a thin seam of sandstone overlying the conglomerate. Total distance to the *top* of this conglomerate below the base of the Island mine conglomerate d 3. 213 by scaling at right angles to a dip of 56° (762) ft.

In Tamarack No. 5 the top of the Pewabic West conglomerate T. 5 b 23, Marvine's 16 is 930 feet below the Island mine conglomerate, but No. 17, the Hancock West comes only 400 feet below.

This appears to be equivalent to No. 16, and some parallelism can be traced in associated flows.

Hole No. 4 is continued by the trenching of Section A.

710 feet horizontally below No. 4 in the section is a 10 feet deep pit 1310 ft. A. T. which exposes trap and at 740 feet and 790 feet are others exposing the conglomerate while at 800 feet an outcrop of trap has been scraped off so as to expose its contact with the foot of the conglomerate. Its thickness appears to be over 60, say (63) feet (76)

Base of this the Pewabic West Marvine's (16) Winona 4. 585+ below the base of (Marvine's No. 17) d 3. 131-212. (825)

THE BEGINNING OF THE CENTRAL GROUP AND END OF THE ASHBED GROUP MUST BE BETWEEN THIS AND 208 FEET DOWN IN HOLE 5.

Record continued by engineer's Section A. From trenches. Zero is at sta. 167 1340 A. T.

This I visited and sampled May 23rd, 1906. It was not plainly ophitic even in the center. The feldspar up to 1 mm. long-x0.1 to

0.2 mm, wide was rather prominent, especially on the weathered surface. The general type is that of a feldspathic melaphyre.

38. Trap outcrop – – extending N. 59° E. -68 (112) hor. width 127
Fluccan seam with copper stains on its base, then brown sandstone. (5) 5

39. *Conglomerate* -85, float copper found here – – lower (12) 15

40. Amygdaloid (10) with epidote and calcite copper seam and trap -137, covered (10) feet, -147 (54) 65

41. Amygdaloid with epidote and quartz 8 and trap outcropping at center -226 (79) 87

42. Amygdaloid with epidote and quartz (15) feet and trap -405 (158)+ 190
– – trap exposed in pits, not absolutely continuous in section.

Amygdaloid with epidote, calcite, quartz and copper -(7) Pit (G)- and trap, in which Win. d 5 perhaps begins, exposed in pits H, I, J, K, L, to 537. For thickness see Win. d 5. below.

Winona drill hole 5. Elevation 1288.8 A. T.

This hole is 1393 feet from drill hole 4. The average dip of the top of the beds between is near 57°; assuming this the top of Win. d 5 would correspond to W. d 4. 1171 and the top of the first amygdaloid at Win. d 5. 77½ to Win. d 4. 1248, or 600 feet below the *base* of Win. d 4. 58, making the thickness of the belt of trap in which the hole starts 180 feet.

Dip of hole 38° to S. 24° 50′. Dip of strata 57.5°. For true thickness multiply by sin 105.5°=.9954 for width by sin 105.5° ÷ sin 57.5=1.19

Surface d 5. 0-d 5. 23.5 23.5

43. Trap d 5. 23½-77½+ that above 54 (54+126=180)
At d 5. 58 much broken with seams. – – I think from grain there is a small fault, making say 20′ repetition here. – – etc. From 64 to 75.5 fine grained. – – This ophite is well-marked and is coarsest at about 36,-about 3 mm., at 44 2 mm., at 53 1 mm.

44. Amygdaloid with copper in calcite d 5. 77½-89½ – – a well-marked contact.
d 5. 83.2 to 84 very hard, fine grained not amygdaloid trap, probably marks junction of two beds – – Very possibly the flow is from d 5. 76-84. d 5. 87 to 89½ epidote trap, fine grained at 92.
Trap to d 5. 92 14 (14)

45. Somewhat amygdaloidal d 5. 92-98½, Dark trap — 101½ (10)
– – at 100 a coarse chloritic amygdaloid passing into a fine grained trap.

46. Amygdaloid d 5. 102-114 and – – feldspathic – – Trap -129 27 (27)
Am. has much calcite partially brecciated, – – chloritic fine grained.

47. Amygdaloid (epidotic) d 5. 129-140 and trap -208 79 (79)
From d 5. 202-206 fine grained.

48. Melaphyre conglomerate? d 5. 208-5. 213 (5)
Greenish material enclosing patches of brownish rock having much the appearance of conglomerate. – – This is a real conglomerate and the trap above is a real ophite but *not* a *marked* one. – – A well-marked altered gray sandstone; dip against core 72°; a little conglomerate at the base. This should be compared with the Allouez *conglomerate* and the Mesnard epidote.

49. Trap d 5. 213-5. 234 21 (21)
– – Coarse, few amygdules, also specked.

50. Amygdaloid epidote d 5. 234-242 and trap -250 (16)
– – Greenish, marked, compact.

51. Amygdaloid d 5. 250-257 and trap -262 (12)
– – A well-marked amygdaloid with flow contact at top.

52. Amygdaloid d 5. 262-266 and ophite -440 178 (177)
The Am. has something the appearance of a melaphyre conglomerate with epidote and considerable copper. At 414 the material is broken and the mottling not so apparent but it is probably the same bed – – but faulted by a fissure running at 60° to the drill hole at 415′ 8″. At 440 it is fine grained and probably the bottom. – – This is the first ophite that Mason notes. Its top is by scaling and at a 56° dip below the base of the conglomerate d 4. 581 785 ft. Can it be the Greenstone? The "Greenstone" is known to thin to the south and be nearly gone at Portage Lake. Much more likely it is the Mandan ophite or some similar lower bed? There is no sign beneath of the Allouez No. 15. At 300 2 mm., at 345 4-5 mm., at 365 7 mm. or so, at 398 3 mm., at 438 bottom *contact*.

53. Amygdaloid d 5. 440-444, and trap -504½ 64½ (64)
Trap is brownish – – and shows minute ophitic mottling well at the base. Top of the amygdaloid below d 4. 585+ 963 ft.

54. Amygdaloid d 5. 504½-508 and trap 524 20 (20)
– at 517 minutely mottled and ophite.

55. Amygdaloid d 5. 524-534.6 10+ (10)
With much calcite. This should be the amygdaloid d 6. 53½-62½ most nearly. With this correlation the dip appears to be again 57½° and the top of this amygdaloid would be 84 feet below the base of the large ophite, 1046 feet below the base of the last conglomerate. On the road N. 28° W. from the Winona power house about 3000 feet is an outcrop, porphyritic and clasolitic, which may correspond to the melaphyre conglomerates d 5. 208-266?

Winona drill hole 6. 1267.9 A. T.

Dip of the hole 38° to S. 29° 47′ E. Dip of the beds 57½°. For true thickness multiply by sin 105½=.995. For horizontal breadth by 1.19.

Surface deposits to rock d 6. 0 to 46 46 *vert.* thickness width

[54]. Trap d 6. 46-53½ 7½ true th. (7½) width 8
– – The bottom of d 5. 508 *to 524*?

[55]. Amygdaloid d 6. 53½-62½, and trap 181 122 (119) 145
– – 53½ is below the base of the last conglomerate (1046)

56. Amygdaloid, cupriferous d 6. 181-195 and trap -211
30 (29) 36
– – The trap is a well-marked ophite. There is copper in the hanging. The amygdaloid is brecciated and almost an amygdaloid conglomerate.

57. Amygdaloid d 6. 211-216, and trap -304 93 (93) 110
The trap is brownish and an ophite up to 3 mm. mottles.

58 and
59. Amygdaloid d 6. 304-316 and trap – – ophite – – – 440
136 (135) 160
Amygdaloid is marked epidotic with copper in sludge. The trap – – two flows having a junction near 394; about 393 it is fine grained, hard and amygdaloidal – – at 357 3 mm., at 367 2-3 mm., from 780 on

is a f. g. chloritic amygdaloid and between that and 399 is well-marked Am. and contact. The trap below is feldspathic, faintly ophitic.

60. Amygdaloid d 6. 440-445 and trap -448½ and amygdaloid d 6. 452
12 (12) 14

61. *Conglomerate* d 6. 452-461 9+

Portions of this conglomerate have a very light matrix giving it a weathered appearance. Its top is below the top of d 6. 53½=d 5. 524 (397) feet and below the base of the conglomerate d 4. 581 (+60 ft.) is (1443) feet. A marked felsitic conglomerate.

This hole does not quite lap Hole No. 7 but is probably paralleled by Section B which is 5000 feet northeast of the line of section. It enables us to estimate the thickness of this conglomerate, which is the Shawmut or Johnson Creek conglomerate. It appears to be there (74) feet thick. If so, its base would be below the base of the conglomerate at the bottom of No. 4 (1517) feet.

This appears to correlate with the Houghton conglomerate No. (14)

	Section B shows:		horz. width
[56].	Trap		45
[57].	Epidotic amygdaloid – – Cf. d 6. 211-216		10
	Covered		
	Trap – – Cf. d 6. 216-304		28
[58].	Amygdaloid, laumontitic, calcitic and epidotic		4
	Trap	(61)	75
[59].	Amygdaloid from 182 to 187 – – cf. 6. 393	(57)	3
	Trap to 240		65
	Shawmut conglomerate to 328 – – cf. 6. 452+	(74)	88

"Johnson Creek conglomerate, thought to be the same as exposed on Misery River at the falls." – – It may be the conglomerate at the bottom of Hole 6 (d 6. 452-461+)

Trap to 365	(31)+	37

This section is made in the N. E. ¼ Sec. 20, T. 52, R. 36, by J. B. McIntosh. The end of this section should overlap drill hole 7 a little. As near as I can judge the beginning of the rock in No. 7 (7.48) is 88 feet of thickness below the top, 14 feet below the bottom, of the "Johnson Creek" conglomerate. The foot trap to the Johnson Creek conglomerate would then be 14 feet thicker than shown in No. 7 or 130 ft.

Winona drill hole 7. 1268.54 A. T. Dip of hole 37° to S. 34° 08′ E. Dip of strata 63°⅓ to 66°. For true thickness multiply by sin 110°⅓=.984. For horizontal width by (.984/sin 63°⅓=.893)=1.10.

Surface deposits to rock 7.48+2=50 ft. vert. thickness hor. width 55

62. Trap d 7. 50- to 148=98 (96+14=110) width 154

Very coarse grained and weathered, large feldspar crystals standing out – – doleritic – – If this were the Kearsarge foot the conglomerate below would be the Wolverine sandstone No. 9. 50½ to 51½ epidotic; 74′ 9″ peculiar core of 2 inches light reddish clay seams in trap, – (clasolitic? L.). – – At 51 doleritic, massive feldspathic, not ophitic.

Seam of fluccan at d 7. 148. Slide fault.

63. *Conglomerate* d 7. 148 to 152⁷‴ 4.7
– – felsitic Calumet?
Another seam of fluccan. – – At the bottom very fine grained.
Melaphyre conglomerate d 7. 152′ 7″ to 166.0 13.3 18.0 (18)
– – is amygdaloid conglomerate of black scoria and red cement. Base

below base of Johnson Creek conglomerate (128)
Amygdaloid d 7. 166-167.8 1.8 (1)
Fluccan at d 167′ 8″
There has evidently been a good deal of disturbance and sliding along this conglomerate, and the possibility that it is the same as one of those above repeated by faulting should not be overlooked.

64. Amygdaloid d 7. 167′ 8″-172 and trap -232 64′ 4″ (63)
Amygdaloid much mineralized with some calcite; epidote vein carrying copper from 172-177; trap dark colored—at 199 ophite 2-3 mm.

65. Amygdaloid d 7. 232-237′ 5″
Fluccan at d 7. 237′ 5″
Trap d 7. 306 74 (72)
– – This trap is barely mottled.

66. Epidote vein, calcite and copper d 7. 306-312′ 7″
Amygdaloid with calcite – – well-marked – – d 7. 319′ 7″
Trap d 7. 343½ 37½ (36)
– – Notably ophitic 2 mm. at 330.

67. Amygdaloid d 7. 343′ 5″-345′ 5″
Epidote vein with copper -347′ 7″
Trap -354 10′ 7″ (10)
Amygdaloid d 7. 354-356
Trap -359 – – not a separate flow? – – 5?

68. Amygdaloid d 7. 359-366 and trap -407+ 44
Melaphyre conglomerate – – ? brecciated scoriaceous amygdaloid – – From d 7. 359′ 7″ to 361′ 7″ and from 363 to 366 also very hard and fine grained. Trap 366-407. End of typewritten records of holes by engineer. In the sections drawn this bed is entered as amygdaloid both in Win. d 7 & 8. It is hard to draw the line between brecciated amygdaloid and some conglomerates. This is especially true of the beds like the *Montreal lode* (Figs. 26 to 28) directly under the Houghton conglomerate. Correlating W. d 7. 354 and d 7. 356 with d 8. 62; d 7. 359 with d 8. 68; d 7. 366 with 74 we may infer that d 8.0 about corresponds to d 7. 294 (1773) feet below Win. 4. 585+ which gives a dip of about 66°.

Winona drill hole 8. 1265 A. T. 314 feet on the section from No. 7. Dip of hole 37°. Dip of strata, correlating d 8. 58 with d 7. 354 is 66° and this is confirmed by the dip of the sandstone. Correlating d 8. 605 with d 9. 88 it is 70°. Hence for thickness multiply by sin 105°=.966+ and for horizontal width by 1.03. Depth 649.6.

Surface deposits d 8. 0-50
– – Ophite 50-58, feldspathic faintly mottled.

67. Amygdaloid d 8. 58-62, with copper.
Trap d 8. 62-68

68. Amygdaloid d 8. 68-77. About 74 feet there appears to be some genuine *sediment*, indurated gray sandstone, etc., with datolite.

– – Feldspathic ophite.

Trap d 8. 77-196	136	132

– – At 110 coarse feldspathic trap, at 133 4-5 mm. but not conspicuously mottled. From 167 down it is more distinct and grows finer. Epidote seam at 100 and a little quartz and copper between 144 and 156. – – This is apparently the flow at the bottom of 7 so that d 7. 366 =d 8. 74 about. There is the same couple of amygdaloids with a streak of trap between and signs of epidote and copper. Thus d 7. 354 = d 8. 58. Whether the seams just above should be grouped as gushes of this flow is not so clear.

69. Amygdaloid d 8. 196-208 and trap to 230	34	(33)

This bed is quite feldspathic.

Fluccan d 8. 230-232	2	(2)

Fluccans are generally a belt of red clay which seems to be the product of slipping and hydration on the overlying trap and they often occur just above conglomerates.

70. *Conglomerate* d 8. 232-282	50	(48)

The bottom 12 feet are sandstone. – – in fact it is mainly sandstone and marks beginning of numerous sediments, largely red sandstone, which must be correlated with conglomerates 12-9, the *Kearsarge* to Wolverine; in the traps there is also a difference. They show copper, are specked and not so markedly ophitic. – – The base of this is below

the base of conglomerate d 7. 166 (397)

Below the base of conglomerate d 3. 213=(825+1517+128+397)

– – – – (2867) ft.

Conglomerates d 3. 213 and d 8. 282 are about 3350 feet apart, thus the average dip we have assumed is 59°. This d 8. 231-236 is a conglomerate with much matrix. The bed is in general a sandstone, the bedding well marked with the dip 77° to the core.

71. Amygdaloid d 8. 282-287 and trap -438	156	(150)

With epidote and copper at d 8. 348-351, quartz and copper 370, distinctly an ophite—at 355 5 mm. From 281-283 is really an amygdaloid conglomerate.

72. Conglomerate and sandstone d 8. 438-450	12	(12)
Base of the above below base of d 8. 282	168	(163)
Base of the above below base of d 7. 166		(560)

– – The conglomerate has abundant matrix and small rounded pebbles. The red sandstones vary 13°-17° from being at right angles to the core.

73. Amygdaloid with epidote and copper d 8. 450-453—really quite good looking. Cf. the Calico lode at the Michigan mine.

Trap	-467		
Epidote seam with copper	-473		
Trap	-476	26	(25)
74. Amygdaloid d 8. 476-480,—from 467 really. and trap -482		6	(6)
75. Amygdaloid d 8. 482-486 and trap -492		10	(10)
76. Amygdaloid d 8. 492-494 and trap -496		4	(4)

Copper here.

77. Amygdaloid d 8. 496-505 and trap -508 12 (12)
At 503 specked amygdules.
78. Amygdaloid d 8. 508-513 and trap -516 8 (8)
At 510-512 amygdaloid conglomerate with gray sediment.
79. Amygdaloid d 8. 516-522 and trap -527 11 (11)
Copper in the amygdaloid sludge, also epidote.
80. Amygdaloid d 8. 527-532 and trap -538 11 (11)
Amygdaloid has epidote and copper, red at top, cold gray epidotic at bottom.
81. Amygdaloid d 8. 538-550
Trap 550-563 12 (12)
82. Sandstone d 8. 563-590, conglomerate -605, then sandstone again to 615, dip 10°-17° 62 (60)
There are fault seams nearly at right angles to the bedding.
The base of this belt, mainly of sandstone, is also found in Hole 9. 88 feet

d 8. 232 to base of d 8. 615 333 (321)
From the base of d 8. 450 to base of d 8. 615=988 is 165 (158)
From the base of d 7. 166 to base of d 8. 615=988 is 700
83. Amygdaloid d 8. 615-625+ Sec. 9. 88+
The trap under is ophitic
8. 563 may be the Minnesota conglomerate, and then 8. 232 would be the National sandstone. There is a resemblance also to Conglomerate 8 and 6.
Bed 8. 432 would then be the Calico lode. Here it is distinctly a conglomerate.
An approximate correlation with the Kearsarge lode is strengthened by frequent signs of copper.

Winona drill hole 9. 1258 A. T. Dip of hole 37°. Dip of strata (correlating d 9. 88 with d 8. 615) 70.5°. Whence for true thickness multiply by sin 107.5° =.954, for horizontal breadth by sin $107\frac{1}{2} \div$ sin 70.5°=1.01.
Surface deposits 55
82. Sandstone and conglomerate (12′) d 9.55-88, 33+
Dip of bedding 73°, mainly sandstone,—that conglomerate is subordinate is characteristic.
The same as d 8. 553-590. The base of the sandstone is epidotic.

Below the base of d 8. 282 (321)
83. Amygdaloid d 9. 88-92 and trap -144, 56 (53)
At d 9. 116 epidote seam. The trap is very feldspathic or epidotized. (21)
84. Sandstone d 9. 144-166, 22
– – red, alternating, fine red mud bands and coarser. Dip of 73° to core well marked. (72)
Below d 9. 88 76
85. Amygdaloid d 9. 166-175 and trap -182, 16 (15)
Trap, epidotic, probably an alteration seam in the amygdaloid.
86. Amygdaloid d 9. 182-184 and trap to 195, 13 (12)
87. Sandstone and conglomerate d 9. 194′ 9″-217, 22 (21)
Last two feet amygdaloidal conglomerate, the rest the same red shale and sandstone as above.

Base of d 9. 217 below base of d 9. 88, 129 (123)
Base of d 9. 217 below base of d 8. 282 (444)
Base of d 9. 217 below top of d 8. 438-450 (12) + (165) + (123) =(309)

Discussion of Correlations.

These 310 feet are occupied by small flows and amygdaloids with some signs of copper and heavy sandstones, on the whole weak beds, and this d 9. 217 is the last sedimentary bed above the Winona lode. For nearly 2000 feet there appears to be no marked sediment. This should be an easily identified horizon. Wyandotte Holes 2 and 1 are evidently below it.

The predominance of sandstone rather than conglomerate at this level is also common at the horizon of the Wolverine sandstone, with which accordingly I am inclined to identify it. That also is underlain by a broad belt of traps with no important sediment.

The Wolverine is Marvine's No. 9. Numbering back (omitting melaphyre conglomerates) would make

No. 18=d 3. 203
No. 17=d 4. 581+ 60, which we have already correlated with No. 16 or 17.

No. 16=absent or exposed in the trenching section? 147 feet below d 4. 581 Cf. also d 5. 208.

No. 15=d 6. 452+ 74 (74)
No. 14=d 7. 148 to 166 (18)

No. 13=d 8. 232 to 282 (48) with fault slides and copper above and below.

No. 12=d 8. 438 to 450 (12)
No. 11=d 8. 553 to 615=9.55-88=(60) sandstone
No. 10=d 9. 144 to 166= (21)

This is too rigid a correlation with Marvine's numbers. It has been shown by Hubbard that the Kearsarge conglomerate probably covers 10, 11 and 12. Again there is a bed of ash or "jasper" above the Greenstone,—the Mesnard epidote. So that I am inclined to think that here a more probable correlation is to group the last three sandy beds as divergent splits of the Wolverine and correlate the *Allouez* as absent (but cf. d 5. 208) or present in the trench of Section A, just S. of the outcropping ridge which would then be the Greenstone.

- (832) feet interval.
Houghton conglomerate d 6. 452+ (74) - - - - - - Marvine's No. 14.
- (128) feet interval.
Calumet conglomerate d 7. 148-166 (18) - - - - Marvine's No. 13.
- (397+321) feet interval.
Kearsarge conglomerate, and intercalated traps d 8. 232-450
Marvine's No. 10, 11 and 12.
(Cf. Houghton section)

Wolverine sandstone and intercalated trap d 9. 55-217 Marvine's No. 9 - - -

From d 9. 217 up to d 3. 213 is (123+321+2739) 3183 feet

From the Wolverine sandstone at Calumet to T. 5 b 12 is (3150 to C & H+972+880+180+40) say 5200 feet.

At the Arcadian the Wolverine sandstone is about 2835 feet below the

Allouez and 3595 below the beginning of the section which is in the Ashbed series, about 251 feet above the Quincy lode and so 1300 feet below T. 5 b 12. This indicates a continuance toward the southwest if our correlations are correct of the diminution of the series which Marvine found. From d 9. 217 to the next marked conglomerate, the Winona which would then be No. 8 we find a thickness of about (1583′). At the Arcadian from No. 9 to No. 8 is (3015′), showing a thinning in something like the same ratio.

From the Wolverine to the Allouez (2835) would at the same rate of thinning bring the Allouez 1420 feet above d 9. 217. It is (2412) feet above d 9. 217 to the base of the conglomerate d 4. 581, but 963 feet below that (at d 5. 440 or 1447 feet above the Wolverine at d 9. 217) is the base of the first ophite noted by such as Mason, a bed 178 feet thick which may well pass for the Greenstone, or a bed immediately below like the Mandan ophite for the whole Hole 5 seems to belong in the Ophite or Central mine group. – – –

88. Amygdaloid d 9. 217-235 and trap -246 29 (28)
– – not a contact.
Epidotic amygdaloid d 9. 246-250 and trap with red specks -273
27 (26)

89 and
90. Amygdaloid conglomerate d 9. 273-303 and trap -413 140 (139)
– – This amygdaloid conglomerate is like the Houghton conglomerate and the beds under it.
Epidotic at d 9. 303, 306, and 316 feet, and at 332 copper in epidote.

91. Amygdaloid d 9. 413-422 brecciated and trap -435 22 (21)
Copper in amygdaloid. – – The trap is fine grained glomeroporphyritic, not at all an ophite.

92. Amygdaloid d 9. 435-443 and trap -448, 13 (12)
Epidotic amygdaloid.

93. Amygdaloid d 9. 448-455 and trap -463, 15 (14)
Epidote, quartz and copper in amygdaloid.

94. Amygdaloid d 9. 463-473 and trap -488, 25 (24)
Epidote, quartz and calcite in amygdaloid – – trap a fine grained melaphyre.

95. Amygdaloid d 9. 488-500 and trap -520, 32 (30)
Epidote, quartz, calcite and copper in amygdaloid.

96. Amygdaloid d 9. 520-525 and trap -634, 114 (107)
Epidote and calcite in amygdaloid – – the trap is coarse feldspathic with chloritic spots.

From base of d 9. 217 (392)

Amygdaloid d 9. 634-648 and trap to 552′ 3″ ?

This amygdaloid seems to be really an amygdaloid conglomerate; the trap below is brecciated. This may probably be correlated with the top of d 10 and d 9. 648 may about correspond to d 10. 118, which would give a dip of 67.5°. But this is on the base of the amygdaloid rather than the top which is not so exact a correlation.

Winona drill hole 10. 1258 A. T. Dip of strata 72° 40′ to 67.5°, i. e., about 70°

as on the Winona lode. Dip of hole 37°. For true thickness multiply by sin 109° 40′=.947, for horizontal width by (sin 109° 40′ ÷ sin 72° 40′)=1.07.

Surface deposits 72

– – fine grained, not ophitic trap to 102, then brecciated -105 then fine grained greenish.

97. Amygdaloid d 10. 72-118 and trap -218, 146+
at d 123 and 125 epidote.
Correlating d 10. 72 with d 9. 634 we get a dip of 72° 40′
better d 10. 102 with d 9. 644
by 170½ faintly mottled; at about 218 a finer glomeroporphyritic base. (146)

98. Amygdaloid d 10. 218-244 and trap -428, 210 (199)
Epidotic at d 10. 222-3 and at the base also cold gray 238 and dioritic at 395 – – (doleritic) at 325-330 amygdaloid streak, at 357-378 coarse faint mottling, a feldspathic ophite.

99. Amygdaloid d 10. 428-466 and trap -472, 44 (42)
– – A. 428-433 poor.

100. Amygdaloid d 10. 472-484 and trap 636′ 7″ – – at 489 doleritic and coarse augite barely visible, 5 mm., at 454 8 mm., at 615 4-5 mm., showing that it must continue some distance.

A cross-cut N. from the Winona shows also a big ophite as far as it goes, 114 feet horizontally, showing that this last bed is one continuous big ophite. The hanging wall of the Winona lode would according to scale have been met in 163 feet more at d 10. 800[1], i. e., the thickness would be (310)

Below d 9. 217 (698) + (392) (1090)

The Winona lode hanging is a slide fault, and is well marked by 6 inches of clay fluccan. Top of Winona lode below base of d 9. 217 about (1090)

The Winona lode varies from 30 to 60 feet wide, is say 32 feet thick and has a sharp well-marked hanging, but the foot is hard with bunches of trap in it. The dip is 70°. Its elevation is 1374 feet 8 in. A. T.

$$\frac{\text{Winona lode to d 9. 217} = 1090}{\text{Arcadian lode to Wolverine ss} \quad 2450} \quad \text{Compare these ratios with} \quad \frac{7.166\text{-}9.217 = 841}{\text{Calumet congl.-Wolverine ss at Arc.} = 1735.}$$

The Winona is probably the Arcadian Isle Royale lode, and the traps of this part of the section have diminished going southwest. It is probable that there is not so much diminution in the upper part[2] of the section as the beginning of the Arcadian section appears to be not so very far from the horizon of the Winona d 4. 581.

– – Since no drill core section is given from the Winona lode for some distance down we will supplement from records elsewhere.

From the Elm River cross-cut we have:

101. Winona amygdaloid 23 and trap 43, 66 (62)
102. Amygdaloid 11, and trap 40 51 (49)

[1]By the grain one would, however, infer a thickness of not over 218.′
[2]In fact if, as I believe, the Chippewa felsite of the Porcupine Mts. is a member of the Ashbed group, there will be an actual thickening.

103.	Amygdaloid 18, and trap 87	105	(99)
104.	Amygdaloid 19, and trap 90	109	(103)

105. Conglomerate which at Elm River was 205 (194) is exposed by trenching on the Winona for a width of 140 feet about 384 feet in horizontal width below the Winona lode. The elevation of the trench has not been exactly determined, but it has probably about a thickness of (180)

Base below top of Winona lode about	(493)
Base below top of d 9. 217 lode about	(1583)

This is (3015) feet at the Arcadian, and the top of this bed marks a lower era of sedimentation, the culmination of volcanic activity apparently lying above, between this and the Greenstone.

This section is continued at Elm River as follows:

Amygdaloid (10) and trap (35)		(42.5)
Amygdaloid (24) and trap (115) an ophite with a scoriaceous top		(131.5)
Amygdaloid on which drifting was done (23) and (trap) 45		(63)
Amygdaloid (17) and trap (79)	(91)	
Amygdaloid (4) and trap (80)	(79)	
Amygdaloid on which they sank (11) and trap (40)	(47)	
Conglomerate (6?)	(118)	
	(572)	

At the Winona, trench J gives:

106.	Trap 112 feet wide	(105)
107.	Amygdaloid 10 and trap in trench I 74 ft.	(70)
108.	Conglomerate (7?) This does not appear in K.	(13)
109.	Trap in trench K not less than	(165)
		(353)

110. Conglomerate exposed directly beneath the trenches and in pits near drill hole 13, from 384 feet horizontally from the Winona for 140 feet breadth and more. Perhaps also the conglomerate in No. 13 down to Win. d 13. 62. Omitting it (252)

Thus the base is below Conglomerate 8 (605)

This conglomerate on the whole I think should be correlated with Marvine's (6) which is (815) feet below (8) at the Arcadian, (722) at the Atlantic section (16).

The records of Holes 11, 12 and 13 are largely from Capt. Peterson's book and the drawn cross-section as many of the boxes of samples were badly decayed.

Tests of some of the mine waters of the Winona mine are given in Chapter VII.

Sp. 20359 is a specimen of a datolite nodule from the Winona mine. A section under the microscope shows quartz crystals which themselves contain crystals of copper and cavities with fluid and bubbles. The little crystals of copper tend to occur in lines running through the quartz and extending out over the larger masses which are crowded between the quartz. Datolite and copper together separate areas of quartz which extinguish together. The quartz is clearly older than and idiom-

orphic against the datolite and there is a hexagonal basal section of quartz imbedded in the aggregate of datolite and reddened with copper inclusions and separated from the datolite by a line of copper. Yellow epidote crystals are sharply older than the datolite and also idiomorphic against the quartz. The epidote is, then, the oldest mineral formed, the datolite the youngest, while the quartz and copper were precipitated at more nearly the same time, though the copper certainly formed later and tended to replace the quartz. It is possible that this might account for all the copper, though I hardly think it.

Winona drill hole 13. 1373 feet A. T. 515 feet horizontally above Hole 11 and 80 feet vertically, 1135 (1066) feet from the hanging of the Winona Dip 36°. Suppose the dip of the strata to be 70° for true thickness multiply by .961.

Begins, it is said, just under Conglomerate (6).

Surface (standpipe) 0-34

110. Amygdaloid conglomerate d 13. 34-62 28[1] (27)

Base below the base of No. 8 (1066+59-493) (632)

below the top of the Winona lode (1125)

Cf. Elm River d 3. 302+ and Elm River d 4. 258+

111. Amygdaloid vein d 13. 62-67 and trap -102, trap -150′ 6″ (cf. E 4 b 3) -- Trap is a well-marked ophite, 2-3 mm. at 75; 3-4 at 95; finer at 112.

112. Vein trap d 13. 150′ 6″ to 190′ 6″, trap -203, -264, 202 (192)

113. Amygdaloid d 13. 264-265-277, and trap -323-370+-108 (104+)

Cf. E 5 b 1 or 2 and E 4 b 4 say (110)

406

An exposure in a trench of epidotic amygdaloid 370 ft. horizontally and 30′ vertically lower is nearly reached, which implies a dip of 68¾°.

-- Amygdaloid and almost conglomerate at 169; epidote to 184 f. g. trap to 201 gradually growing coarser to 226, 4 mm. and then finer, 2 mm. to 250. The amygdaloid then well-marked, ophite 3 mm. at 302 and at 343 at 364 1 mm. or so.

114. The section from the bottom of 13 to the top of 11 is supposed to have been sufficiently exposed by trenching, being one heavy bed of ophite with 8 feet of epidotic amygdaloid on top, its foot extending down to Hole 11. 99. It is laid open in trenches C, A, B.

The large ophites at this horizon are also found in E d 5.

Winona drill hole 11. 1295 A. T. 515 feet from Hole 13 and 80 feet lower. Consequently if the strata dip 70° the top of d 11 would have to correspond to d 13, 532 or (452) feet below the amygdaloid conglomerate. Dip 36°. Whence for dip of strata of 70° to get the thickness multiply by .916.

There is a very considerable distance along the strike between 11 and 13 and consequent chance of error owing to veering of the strike or cross-faults between.

Surface (standpipe) d 11. 0-35′ 5″

[1]This may be counted as the base of (6) or as a scoriaceous amygdaloid with the underlying.

114. Trap d 11. 35-89, mottled to 96′ 7″, fine grained -99 (243)
Amygdaloid d 11. 99-101 (2) ?
This is probably the base of the big ophite exposed in trenching which would be below 13. 63.

115. Conglomerate d 11. 101-133 and sandstone -168, 67 (64)
Dip varies from core 70° to 72° indicating a dip of 72° to 74°.
Base of d 11. 168 below base of d 13. 62 (613)

Below base of Winona congl. (1245)
Cf. Elm River d 4. 51-258. Is this Conglomerate 5. It is largely and mainly sandstone.

116. Amygdaloid d 11. 168-178 or 182 and trap -183, 15 (14)
Brown

117. Amygdaloid conglomerate d 11. 183-198′ 9″ and trap -235′ 4″, and to -274 91 (88)
Vein brown. An ophite. Plain mottling at 230 3-4 mm.

118. Amygdaloid d 11. 274-286 and 305′ 9″ and trap -342 (?mottled) -396, trap -457, epidotic -460, 186 (178)
Well-marked up to 3 mm. at 320, at 388 7 mm., at 442 1-2 mm.
Vein copper cores and washings. An ophite.

119. Conglemerate d 11. 460-536, amygdaloid conglomerate 544-546, hard gray sandstone -544 (80)
Some copper noted near top of conglomerate. 480-482 sandstone also at 518 and 535 feet. The conglomerate has bands of red sandstone in it. Dip about 70° against hole. Is this Conglomerate 4?
Base below base of d 11. 168 (360)

Base of Winona (1605)

120. Amygdaloid d 11. 544-546 and trap -555 11 (11)
The trap is soft.

121. Amygdaloid vein d 11. 555-599, soft trap with copper -602 and trap to the end 606+ 51+
This is probably the ophite at the top of No. 12. The box has a lot of other amygdaloids, conglomerates, etc., which is probably from some other hole.
The combination of sediments and ophites reminds one of the Atlantic cross-cut and the base of the Arcadian section, and is very different from what we find above Conglomerate 8.

Winona drill hole 12. 1265 feet A. T. It is 546 feet horizontally and 30′ vertically lower than No. 11, i. e., the top is equivalent to d 11. 545. It is 364 feet more to the S. E. corner of the Winona property. Dip of hole 36°. Capt. Peterson's record is given,—it varies but slightly from Mason's cross-section.

Surface, standpipe 50, casing 55. – – Begins in an ophite 2-3 mm. – –

121. Ophite 70′ 2″, trap -71′ 9″ veins -75, trap -89′ 9″, vein is hard with epidote, -116′ 5″ trap -135′ 3″ trap.
–138′ 4″ hard green epidote. – – Amygdaloid.
–155 trap. – – Mason classes 69-72 and 93-101 as amygdaloid. The bottom is equivalent to d 11. 700 and the full thickness is d 11. 700-555 (140)

Below d 11. 168 (510)

122. Ophite; amygdaloid d 12. 155-171 – – a gray-green amygdaloid conglomerate, trap -179, -223′ 5″
-253, 98 – – an ophite with mottles 4 mm. at 221.
123. Ophite; amygdaloid 12. 253-261 – – conglomerate for a foot or two; red trap with quartz -264, trap -272, with quartz to 274, trap -286-322, – – all these ophite 69 (66)
124. Amygdaloid with calcite – – red and white, well-marked, d 12. 322-329-355′ 4″ – – at 352 4 mm. ophites – – at 341 with lumps in relief, at 360 ophite, at 370 7 mm., at 410 2-3. – – trap -367′ 6″, green with copper -370′ 1″ trap -440″ 3″ 118 (114)
125. Amygdaloid d 12. 440′ 3″-447′ 10″, sort of vein trap -459 19 (18)
126. Amygdaloid vein d 12. 459-484, trap -486′ 8″ – – really indurated sandstone to 485, then amygdaloid, possibly Conglomerate 3.
127. Amygdaloid vein -495, trap -500, vein trap with some copper to 502 feet, trap -553-573, 114 – – fine grained, not ophitic. (110)
– – Amygdaloid conglomerate.
128. Amygdaloid vein 573-601′ 6″, soft trap -609, 36 (35)
– – with sediment.
129. Amygdaloid vein 609-621, trap -626′ 11″, the *end* 18 (17)

below d 11. 544 (equivalent to d 11. 1172) (602)

Below d 11. 544 in Hole 12 we apparently pass into the horizon of the Elm River Holes 5 and 6 while 1, 3 and 4 and the cross-cut are as evidently above. The base of the section can not be far from the Baltic lode and conglomerate (3).

Note d 12. 367-502, etc.

§ 23. WINONA TO LAKE. (Pl. XIII.)

The next property to the Winona, jointly managed and operated with it, is the King Philip. The Winona lode, which we correlate with the Isle Royale-Arcadian has been continuously followed between them. This brings us on to Plate XIII, the region of the Lake mine in which drilling has been so continuous that though the map was prepared for the report for 1907 and indeed a special edition issued, it was not up to date by the time that report was written and is not now. It will be noticed that above the Winona conglomerate 8 there is (1,400 feet) over a quarter of a mile up to Winona d 9. 217 in which are no conglomerates and that (above and) below they are abundant so that counting to 13.62 we have (730) feet largely sedimentary. Even below that in Winona d 11 are conglomerates. With that in mind there are outcrops enough to trace the horizon pretty safely down to Sec. 15, T. 51 N., R. 37 W. It must be remembered that while one may curve the formations along gracefully through Plates XI, XII, and XIII, the curves only indicate our ignorance in drift covered country; that there are probably straight bits with breaks at intervals, which little by little the diamond drills will expose. Opposite Section 15 in the upper part

of the formation comes in a felsite, a red, fine grained acid rock found by Hubbard and Fuller, which may be continuous to the Wisconsin line, and is an important horizon for correlation. It appears to be the felsite of the Porcupines or as it is called in Gordon's report on Black River, the Chippewa felsite. The early geologists called it jasper, red trap (a fitting name), etc., and the flow lines were taken for relics of sedimentary banding. I have supposed it to belong in the horizon of the Ashbed group.[1]

The drilling now going on also[2] enables us to bring the horizon of conglomerates south of the Evergreen Bluffs back so far as the middle of Section 29, T. 51 N., R. 37 W., and thus helps in correlation with those south of the Winona and King Philip. The position of this felsite on Section 17 associated with conglomerates, and only about half a mile below the course of the Great Copper Harbor conglomerate on Sections 4 and 33 of the township N. and nearly two miles above Conglomerates 8 to 6, makes it clear that it corresponds to the felsite on Section 19 of the same township, and to Holes 1, 2 and 3 or higher in the Winona cross-section. A little beyond, in Rockland, felsite comes about 3,000 feet below the Great Conglomerate and just at the base of a series of "Ashbed"-like rocks, exposed along the railroad in Section 8, T. 50 N., R. 39 W. and above a series of ophites. This would then bring it in the horizon of the "Mesnard" which appears to be a bed of fine ash such as would be the wide spread equivalent of a volcanic eruption of acid rocks. This is my correlation but would imply a correlation with Winona just above Winona drill hole 5. But this would make the distance from the felsite to the conglomerates south of the Evergreen Bluffs on the Lake property too great. Moreover, if these conglomerates are 8 and 6 and the National sandstone and Minnesota conglomerate are normally above them, then the Kearsarge lode should be developed in the Michigan and similar mines. There is no labradorite porphyrite associated and the correlation of the "Calico" lode and the Kearsarge lode has not been suggested by any one else.

We may assume that the dips opposite the Indiana are very flat. They certainly are flatter than at the Winona, but even a dip of 36° (that at the felsite) all the way would convert 9,300 feet (which is the least we can assume the distance across the strike from the felsite on Section 8, T. 51 N., R. 37 to the conglomerate on Section

[1]The recent discovery of felsite way down in the Indiana, opens a possibility that it is an intrusive neck or feeder to this felsite, but I am inclined to believe that it is one of the lower series of felsites, like that of Mt. Houghton, associated with Conglomerate 8. Our correlations would then be strengthened.

[2]News Bureau, March 12, 1910.

10) into (5,500) as against (6,224-2,155) less than (4,100) at the Winona. Unless our correlations are wrong we must assume (for I do not think there is any possibility of a thickening of the formation this much) either extremely flat dips or that the felsite on Section 8 and the conglomerate on Section 10 are also separated by a fault, of one of two classes. It may be conceived as a strike fault throwing the southeast side down. Of this kind of a fault there are distinct indications,—to such a fault may be due the escarpment of bluffs that lie north of the Lake and Mass. Secondly one may think of a fault running through the Indiana properties about south and throwing the east side south. Drilling now in progress may settle the question.

§ 24. LAKE. (Pl. XIII and Fig. 51.)

The Lake property early excited interest by an abnormal strike. From the drill holes I determined the same and then an outcrop of conglomerate to the west showed that the strike was indeed nearly north (N. 60° E.).[1] Since the formations in the bluffs on the north side of Section 31 are certainly running with the general trend of the range, a large fault almost certainly runs through the property,—probably more than one. Abnormal strikes are, however, quite customary near the great Keweenaw fault. Compare, for instance, the Baltic lode twists on Plate X. There is, therefore, a good deal of uncertainty in connecting the upper and lower parts of this section.

Beside the section shown in drill holes there is above them a fairly continuous section of traps and amygdaloids dipping about 40° exposed in the bluffs which extend from the north quarter post of Section 31. (See File 15-29.) It is essentially the same as that shown in the Adventure mine and at the Mass. It continues drill hole 2 upward and shows that above the conglomerate of drill hole 2 there is for over a thousand feet no conglomerate.

This makes the correlation of that with the Winona conglomerate the more likely. The beds exposed are also feldspathic, *not markedly* ophitic,—a character which helps us in identification.

An old diagram (File 15-8) from Dr. Rominger is of historic interest as to the names applied to the amygdaloid lodes and may be summarized.

---

[1]Recent developments on the Algomah indicate that the lode continues on this strike to the center of section 3 south, and drilling on the South Lake, which on Plate XIII is called the Aztec, and developments on the Lake property have led to a suggestion advanced in the report of the South Lake Mining Company for 1910, that the lode curves around to the northwest and finally dips south. See appendix.

"Knowlton" vein	width 10–15 feet	at 0	(268)
Piscataqua	3	"400; at 42 dip	
Champion	15–12	"1000	(669)
Adit at side of bluff			
Ogima vein	5–6	"1130	(763)
Evergreen	4–40	"1280	(857)
Evergreen shaft		"1480	(1091)

The coordinates of these lodes and the drill holes (south and east of the north quarter post of Section 31, T. 51 N., R. 37 W.) are as follows:

	South	East	Elevation above datum	A. L. S.	Inclination angle	Direction
Knowlton	140.17	673.94				
Butler	597.64	659.30				
Evergreen	514.16	2297.67				
No. 2 hole	712.81	1520.67	103.2		66° 20′	S. 33° 40′
Zero	484.74	366.78				
No. 1 hole	1200.	580.	83.8		no rock	at 337 ft.
7	5200	2600	170.	488	60	S 20 E
8	2200	1000	68.		no rock	at 250 ft.
5	3680	1960	94.1	408	62 26	S. 27 58 E.
4	4337.78	2069	108.3	422	60	S. 66 E
3	4123.92	2195.47	105.4	419	60	S. 66 23 E
6	4337.78	2369.61	127	441	55	N. 20 W
9	4025	2600	127	441	60	S. 20 E

Geological Cross-Section at the Lake mine (Fig. 51, File 1427). *Lake drill hole 2.* 712.81 feet S., 1520.67 feet East of the N. quarter post of Section 31, T. 51, R. 37. Elevation 103.2 above local survey datum, about 425 above Lake Superior and 1027 A. T. Planned to go down at a dip of 66° 20′ toward S. 33° 40′ E. This is intended to be practically at right angles to the formation. But the dip on the Butler lode is 34° to 38° more probably and the inclination of the sandstone bedding between 2.611 and 2.660 below indicates an average inclination of 16°⅔ from being struck at right angles by the core. Estimates of the strike of the range at this point vary from N. 75° to N. 58° E. It seems to me probable that the latter figure is more nearly correct, while there are a lot of little faults that make the general trend more easterly. But the reduction factor required to reduce the distances along the diamond drill hole to those along one with the same dip at right angles to the strike will be negligible, being less than those due to deviation of the hole,

For instance 75° 20′-55° 20′=20°; tan 20°=.365; .365 x cos 66° 20′ (dip)=.146 tan-1 of .146=8.5°; cos 8.5°=.989, but the factor is probably nearer 1, as the true strike is probably less than 75°. On the other hand the dip is probably nearer 38° which we shall take and to get the true thickness we must multiply by sin 66°20+ the dip, say 114° 20′ or 75° 40′=.969. This has been done with the slide rule.

1. Overburden, clay till d 2. 0-34. Vertical depth (31)

   Abandoned brick yards are near. The clay is very heavy but somewhat stony.

2. Melaphyre, ophite. Evergreen lode and foot (83)

Amygdaloid d 2. 34-46? (12)

Trap with amygdaloid spots d 2. 46-120 (71)

The amygdaloid is a reddish chloritic amygdaloid with copper—the Evergreen lode presumably, from 43-46 and at 47 and 71 are amygdaloid spots. There are occasional pseudamygdules pseudomorph after feldspar probably. The ophitic mottling is

at 80, 85, 90, and 112 feet

3 mm., 1-2 mm., 2 mm., and 2-3 mm.

This is so irregular that I suspect carelessness in placing the cores, but it may be due to faulting.

2. Ophite (63) (146)

Amygdaloid d 2. 120-128 (8)

Trap d 2. 128-185 (55)

From 120-124 may be base of the floor above, from 120-122 being faint and at 124 a few inches of chloritic amygdaloid, but from there to 128 the bed is light gray-green, well-defined epidote amygdaloid with brecciated chloritic seam at base. Amygdaloid spots occur in the trap. The mottling is

at 130, 145 to 150, 156 feet

1 to 2, 2-3, 2-3 mm.

At 156-161 it appears to be fine grained feldspathic with amygdules of chlorite rarely calcite.

3. Melaphyre (48) (194)

Amygdaloid d 2. 185-190 (5)

Trap d 2. 190-234 (43)

The hanging contact of the amygdaloid is marked and it is green and red and white brecciated. The trap is massive.

4. Ophite (part of the previous belt?) (23) (217)

Amygdaloid d 2. 234-241 (7)

Trap d 2. 241-257 (16)

The amygdaloid is sparse, red and green, and at 245-250 there is a 2 mm. ophitic mottling. But this bed perhaps belongs with the one above or is faulted. The cores are broken in halves lengthwise by a seam running at an angle of 15.5° with the core, and the grain is different in coarseness on one side and the other. If this seam be supposed vertical its strike must be either about N. 17° W. or N. 50° W. A seam in a pit in a gap over the Evergreen lode seems to indicate cross-faults running N. 15° W. to S. 15° E. and there are other evidences in this region of displacements having this trend.

5 &
6. Ophite (disturbed) (180) (84) (481)

Amygdaloid d 2. 257-259, and 274-289?

Trap fissured and seamed, faulted, 295-306, relatively little core down to 338.

Decomposed ophite d 2. 360-531

The mottling is at 407 and 464

3 mm. and 6 mm. (faint) respectively.

and then grows finer to base. There is a seam at an angle of 45° to the

drill hole at about 360 feet. It is clear that there is a heavy trap 150 feet thick or so surrounded by some disturbed beds including very likely another flow.

From 253 to 306 the hole evidently passes through a belt of disturbance.

7. Conglomerate 8, the Winona, d 2. 531-571 (39) (77.5) (560)

Sandstone d 2. 571-611 (39)

The conglomerate contains various types of felsitic pebbles. The sandstone as compared with the Eastern sandstone of Hole 7 is darker, finer, heavier, more cemented. A magnification of 5 diameters barely shows individual grains, largely not quartz. The bedding shows well and varies from 6°½ to 24° from being at right angles to the hole, averaging (21 observations) 16°.6. If we suppose the strike to be at right angles to the direction of dip of the hole, this would mean a dip of 40°⅓, or if the strike is N. 75° E. 38°, quite such dips as are probable.

The total thickness between this conglomerate and the top of the Evergreen is about 500 feet. This would bring it about in the position of the Caledonia or Nebraska conglomerate of the Mass mine.

8. Melaphyre (104) (663)

Amygdaloid d 2. 611-613 (2)
Trap d 2. 613-718 (102)

The amygdaloid is well-marked and bears copper. Cf. Adventure section belt 16. The trap decayed looking, feldspathic, coarse, light gray, the feldspars up to 2 to 3 mm. long at 679.

9. Amygdaloidal conglomerate d 2. 718-742 (22) (684)

At the beginning a few inches of red argillite passing into a conglomerate with gray sediment and dark and white scoria of amygdaloid; includes the amygdaloid of the underlying trap. This might be called a "calico lode." Capt. Wearne says it looks like the lode of that name 140 to 150′ above the Minnesota conglomerate.

10. Ophite (750)

Amygdaloid? d 2. -742
Trap d 2. 742-810 (66)
At 760 2 mm. mottling

11. Feldspathic ophite (69) (819)

Amygdaloid d 2. 810-813 (3)
Trap d 2. 813-873 (58)
Bottom amygdaloid 870-879 (9)

12. Conglomerate 6? (879-918+) (41+) (860)

Marked felsite conglomerate, good sized pebbles. Dip in one place appears to be 26.5° from being across the core. This section is not now continuous as Holes 1 and 8 did not reach rock.

Lake drill hole 1. 1200 ft. S., 580 E. of the N. Q. P. of Section 31, T. 51, R. 37. Elevation 83.5 above local datum (which is 314 above Lake Superior) went 337 feet without finding rock.

Lake drill hole 8. 2200 ft. S., 1000 E., Sec. 31, T. 51, R. 37. Elevation 68 above local datum, 250 ft. deep, also did not reach rock.

The next hole is No. 5, but its distance in the geological column below d 2 is entirely uncertain as the strike has apparently changed many degrees.[1] The distance between Hole 2 and Hole 5 is 3000 feet and that must probably correspond (faults apart) to not less than 1500 feet. So that the top of a conglomerate which occurs below the bottom of d 5. 738 would be probably over 2200 below the Evergreen and 1453 below the top of the conglomerate at the bottom of Lake d 2.

If the strike is nearly north as it seems, Holes 3, 4, 5, 6, 7 and 9 all overlap each other extensively and that really seems to be the case. The highest horizon seems to be reached by Hole 5, which we therefore use as a standard so far as we can, but in all there appears to be faulting and disturbance.

Lake drill hole 5. 3680 feet S., 1960 ft. E. of the N. Q. P., Section 31, T. 51, R. 37. Elevation above local datum 94.1 (408 A. L. S.), put down at an angle of 62° 26′ to S. 27° 58′ E. It was 127 feet to bed rock. From this hole is a continuous stream of about 1 cu. ft. a minute at a temperature of 45°. Analytical tests show a notable amount of Cl. from the upper rock levels, but it is nearly tasteless, as follows:

Cl 760 parts per million
SO_4 82
Ca 24 or 10
CO_3 25 (or 15+18)
Na_2 as Carbonate 14

To reduce from thickness along the hole to true thickness we assume a dip of about 40°, somewhat flatter than the surface dip but agreeing with some seams in the hole and also with indications of flatter dips in the correlations. For 4 and 3 the corresponding reduction factor is .97, for 6 it is .455.

1. Feldspathic ophite d 5. 127-207 (200)+

   This also appears to occur in d 4. 108-277

   The coarsest augite at d 4. 96-147 and d 5. 140 shows in sunshine about 5 mm. cleavage fractures, but there is so much feldspar that the mottling does not show otherwise. At d 5. 160 is a seam at 14.5° with the core, at d 5. 190 another at 21° 20′. These may be nearly vertical seams running a little east of north along which displacement has taken place, or as they have an easterly dip the strike may be more westerly. At d 4. 96 there is a doleritic band making an angle of 66° with the drill hole, and these are usually parallel to bedding. With a northerly strike a dip of some 50° would be indicated.

2. Melaphyre (31) (231)

   Amygdaloid d 5. 207-223 (14)
   Trap d 5. 223-242 (16)

   The amygdaloid is epidotic, the base well-marked and probably corresponds to d 4. 277.

3. Feldspathic melaphyre (41) (272)

   Amygdaloid d 5. 242-250 (7)
   Trap d 5. 250-290 (34)

   This trap is slightly amygdaloid and porphyritic, some of the feldspar being a little more conspicuous. This is also characteristic in 4 about 301. d 4. 277-340 (66) appears the same and it appears also in d 3. 92-

[1] There is drilling going on in the intervening space and on the South Lake and North Lake properties to the west and to the northeast. There are uncertainties caused by faults, and the Adventure cross-section is prodably as good as any for filling in the gap.

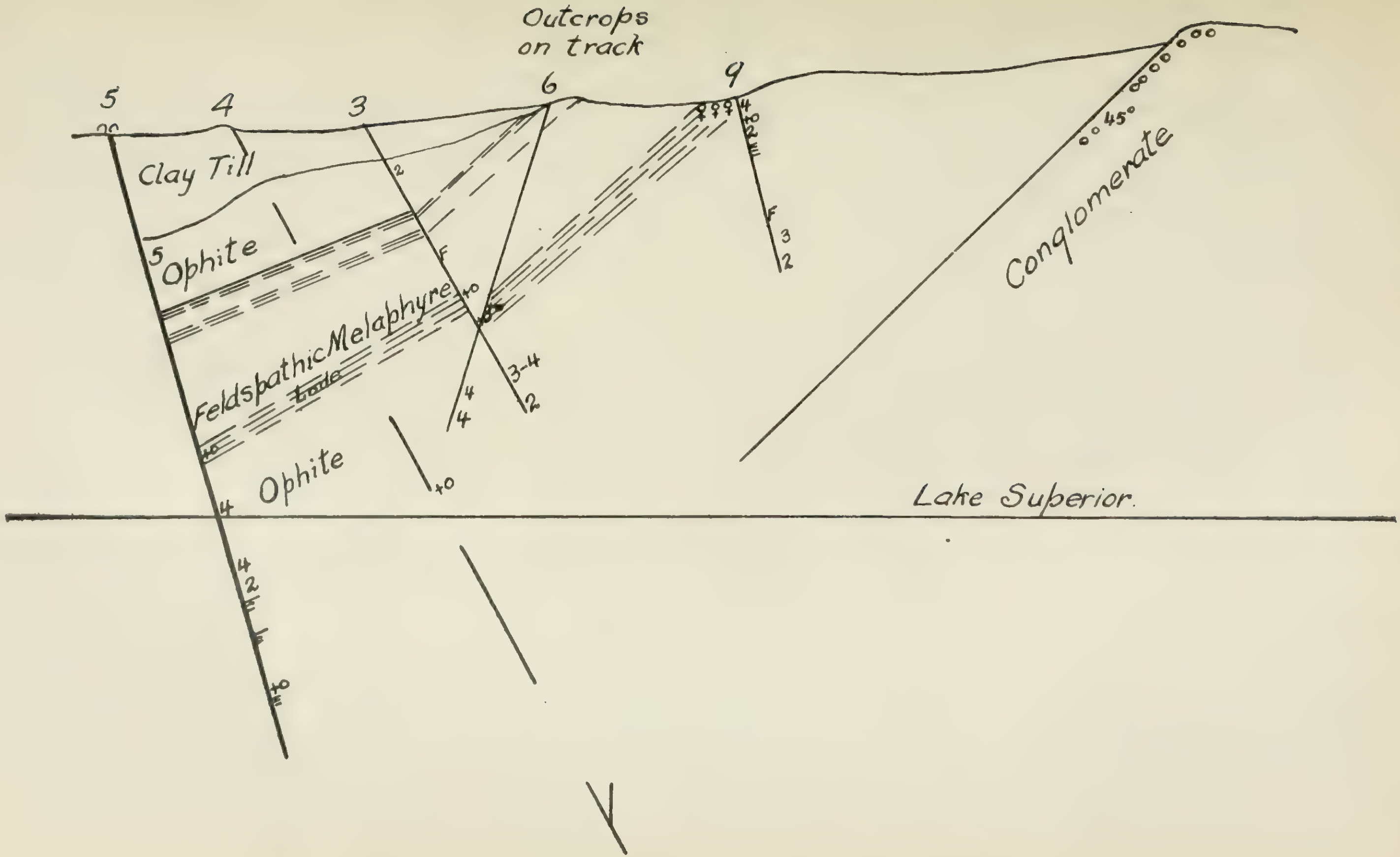

FIG. 51. CROSS-SECTION OF LAKE COPPER COMPANY'S DRILLING.

120. The larger feldspars are up to 6 mm. long, but there is no sharp distinction between them and the smaller.

4. Feldspathic melaphyre (70) (342)

Amygdaloid d 5. 290-301 (9)
Trap d 5. 301?-372 (61)

The amygdaloid banding and flow lines seem to be at about 45° to the diamond drill in No. 5 at 372 to 400 indicating with a northerly strike a dip of about 50°. This is presumably the same as d 4. 343-358-425 (80) which, however, appears to be faulted. d 3. 121-129 a fine grained red and white glomeroporphyritic amygdaloid might be this or the amygdaloid above but the trap to d 3. 208 and the whole thickness in 3 of (87) feet agrees better with this.

5. Ophite, the top of which is the LAKE LODE (120)
Amygdaloid d 5. 372-401=29
Trap d 5. 401-558=157

The amygdaloid is prehnitic and has forms like porphyritic crystals with a speck of copper at 381, and it remains a fine grained slightly amygdaloidal melaphyre with the trend of the blotches at 45° to the hole, as far as 401. The augite mottling is at

420,	433,	451,	462 much seamed,	460,	488,	513,	533,	538,	550 feet
2,	2½–3,	4,	2,		3,	2–3,	4,	2–3,	1–2,	1 mm

The coarsest mottling reached (4 mm.) would indicate a flow about 120 feet or somewhat more thick. There seems to be a distinct faulting by which 451 and 513 are about equivalent. The east or lower part of the lode is thrown down the hole 62 feet which would mean a horizontal heave of the outcrop to the east 85 feet.

Such a fault would account for the relatively flat dip from drill hole 6 to 5, and just such a horizontal displacement would bring the dip about into line. I think therefore it is not safe to assume over 120′ thickness for this belt.

In the drill holes it often appears thicker. Is this always due to duplication by faulting?

Compare the following figures.

d 5. 372-558=186 (158)
d 4. 425-629=204 (at about 579 5 mm.) (200)
d 3. 208-360+20 or so=172 ± (168)
d 6. 236-430+ leaving off in 3-4 mm. ophite (86+45 to 60)
d 9. 8-58 beginning in 4 mm. ophite (58x2+) crossing a calcite and copper vein at d 9. 29

6. Feldspathic melaphyre (38)
Amygdaloid d 5. 558-563 (4) d 9. 58-64 (5)
Trap d 5. 563-603 (34) 64-90? (22)

This amygdaloid is marked. The trap feldspathic. At 580 to 583 is a green streak, a seam of calcite making about 66° with the hole may be parallel to the dip.

Cf. Amygdaloid 4. 589 or 613 (fault) -629
Trap feldspathic faintly ophitic 629-767
Faintly ophitic 2 to 3 mm. at 708

7. (43)
Amygdaloid ? d 5. 603-613 (3) d 9. 90-95? (4)
Trap? d 5. 613-660 ± (40) 95-130 (cf. 4. 677)

Amygdaloid is coarse, calcite and chloritic, the trap is in small broken pieces, possibly with some porphyritic crystals, and slightly ophitic 1 to 2 mm. (Cf. d 4. 767)

8. ——— (66?+ about 100)

Amygdaloid d 5. 660-680 (17?) d 9. 130-160

Trap d 5. 680-738+ (58 +) 160-246+

The upper amygdaloid is well-marked with a little copper. Flow directions seem to make an angle of 56.5° with the hole. The trap is fine grained with chloritic amygdules in spots. At d 5. 698 (about center 33′) there is a 1-2 mm. mottling and amygdaloid spots too and it keeps of about the same grain so long that one is tempted to infer that the bed is cut very obliquely.

In d 9. below 130 there is an epidote and calcite amygdaloid and a heavy epidote vein at 174 feet. The mottling is as follows:

at 163, 200, 232, 242
3, 2, 1–2, 1–2 mm.

Thus as the grain is getting finer it must be more than half way through the flow.

In d 4. there are no well-marked amygdaloid belts and toward the end it is a perfect net-work of seams. We may note the grain at the following points:

at 786, 840, 849, 858
2, 2–4, 5?, 5 mm.

At 767 the core is in small pieces with spots of amygdaloid, at 790 is a light green bomb of amygdaloid. From 849-858 is full of seams. The general impression is that there is an ophite 120 feet thick or so.

Lake drill hole 7 (if the strike is near north) would overlap drill holes 4 and 5 down to the point (433) where it is cut off by the Eastern sandstone.

The record is:

Feldspathic melaphyre d 7. 12-74

Amygdaloid d 7. 74-78

Feldspathic trap ophite d 7. ?78-198

Amygdaloid and breccia red glomeroporphyritic (like d 3. 121-129) d 7. 198-202

Chloritic feldspathic amygdaloid d 7. 202-215. These resemble Belt 4.

Feldspathic melaphyre (feldspar laths, 1-2 mm., chlorite 2-3 mm., on a red ground of augite and olivine) 215-250 growing more and more seamed. At 253 epidote and calcite, possibly the lode.

Ophite d 3. 253-264

At 319 faint, dark, much fissured[1], at 347, 357
1–2, 2, 3 mm.

This *may* be the ophite foot of the lode, or perhaps Belt 8. At 364 is a clay seam, at 370 a chloritic banded amygdaloid spot, like d 4. 677. At 385 is a marked seam at a 45° angle to drill, with calcite seams at 29° and across the hole. At 410 are heavy seams parallel to the hole, the rock highly feldspathic with glomeroporphyritic seriate feldspar up to 3 mm., which continues to 433, when the Eastern sandstone begins. This is for two inches heavier, harder, more compact, but even in this the rounded

[1] One set of seams at 39° with the hole and the other at 52°, also at right angles to each other.

(1, rarely 3 mm.) quartz grains are distinct, the color light to white banded, and by 455 it is white sugary quartz, with occasional flesh colored feldspar and little cement.

This may be represented by d 4. 629-677 but that is not an independent. flow. Both in d 5 and d 4, toward the bottom, approaching the Eastern sandstone the beds are more disturbed and harder to make out. Lake d 9 below 95 is feldspathic to 130, where it is epidotic and calcitic. Thus in hole 7 the section hardly goes below Bed 8. On the other hand going east across country we *seem* to have a longer section.

9. Melaphyre? (70)

Between the bottom of Hole 9 which seems to be near the bottom of a flow and the conglomerate east of it there is according to the cross-section room for 80 feet of trap.

Total from hanging of lode to conglomerate – – – – – (371) ft., from beginning of rock in d 5.– – – – – – – – – – – – – – – (713) feet.

10. Conglomerate, running N. 6° E. for several hundred 10+ feet at a horizontal distance of 550 feet from the hanging of the lode. The apparent strike varies from 5° to 10° N. of E. and the dip from 45° to 48°. Its thickness can not well be less than 10 feet.

11-14. Covered for a horizontal distance of 700′ (490)

15. Conglomerate exposed on creek and in pits and trenches, possibly a faulted repetition of 10. (40 to 140)

Strike N. 12° E. Dip 28°.

16. Ophite (100) (240)

Amygdaloid on creek

Trap 3 mm. ophite.

17. Amygdaloid (100) (340)

Trap 3 mm. ophite last on creek in Section 32, T. 51 R. 37 before Eastern sandstone.

To the northwest of the Lake property in Section 25, T. 51, R. 38, and important in determining the horizon, are heavy ophites with coarse grain found around the Toltec shafts. Compare the belt on which the Powder House stands north of the National mine sandstone in Rockland. Still farther north in Secs. 19 and 24, T. 51, R. 37, and also in Sec. 33, T. 51 N., R. 38 W. is felsite, about 8660 feet from Hole 1,—at a 41° dip about (5700) feet of thickness. This felsite like that in Sec. 9, T. 50, R. 39, just north of Rockland and on Section 17, T. 57, R. 37, is close under the Great conglomerate and Eagle River groups extensively exposed in Section 24, T. 51 N., R. 38 W., and must be high in the series.

But if the conglomerate in Lake Hole 1 is No. 8 as A. H. Meuche thinks, with weighty reasons, the section, as compared with the Winona, must be (about 6181 as against about 3869) very much thicker, over 2000 feet. A correlation of the National sandstone and Minnesota conglomerate with 8 and 6 I was once inclined to favor. To accept this other correlation is to assume that the section is thickening mightily or that a slide fault has cut a good bit out of the Winona section, or that an upheaval fault like that of the Porcupines and the great Keweenaw fault has repeated the section here. There is, to be sure, a cross-fissure going just a little west of the gap through which the road goes, but there is but little displacement as the correlations show. I do not think we can here possibly depend on cross-fissures to help out the difficulty, but there are indications

of strike faults. If it is near an old volcanic focus, with felsite intrusions, we may expect some part of the section to thicken.

On the other hand, in crossing faults there is a gap in our correlations and there remains, *so far as the sediments are concerned*, a possibility that the National and Minnesota beds correspond to No. 8 and 6 and that the conglomerate beneath the Evergreen bluff which is an almost continuous scarp from the Lake to the Michigan mines, may be lower beds or the same beds repeated. Above Conglomerate 8, however, there is not so marked an ophitic texture as above the National sandstone.

The "Aztec" in the west half of Section 31 is now the South Lake. It is drilling south of the bluff. An 1864 record (File 15-14) of the bluff gives a dip of 45° and an adit 408 feet long exposing (amygdaloid) lodes

at 85 A (60)
137 B + (30)
280 to 295 ft. + (100)

The profile indicates these lodes at the surface and also two others,
one (70)
and the other (Hilton) higher[1] (95)

§ 25. ADVENTURE (Fig. 52 and Plates XIII and XIV.)

The Adventure is separated from the Lake by the west half of Section 31, T. 51, R. 37 where the "Aztec" (now South Lake) property lies. The continuous bluff exposures, broken only by short gaps, enable us along here to locate more definitely cross-fissures which displace the formation slightly. The Conglomerate No. 15 of the Adventure section is without question also the first of those of the Lake property.

The maps show the general course of copper beds, and the Nonesuch sandstone and conglomerates are exposed just off Plate XIV, north of Greenland, about 1,500 paces north of the northeast corner of Sec. 27, T. 51, R. 38 in Sec. 22 where a conglomerate is extensively exposed along the 560-foot shore line and is underlain by a dark basic sandstone which dips 11° to 23° to N. 25° W. This is about 12,300 feet (8,200) feet or less above the coarse ophites at the Toltec mine and the exposures are not continuous enough to warrant a section.

Adventure Cross-section. Holes 2, 3 and 4 are from the Knowlton vein running *up* at an angle of 23°, 30° and 27° respectively.

Hole 5 is from the foot of the Evergreen about 800′ horizontally under Shaft No. 3 on the Knowlton vein, pointed down at 46°.

Holes 6 and 7 start close under Conglomerate 8, the Winona at the same angle.

Hole 1 is near the extreme S. E. corner of Sec. 36 at an average angle of about 65°.

The dip of the formation is supposed to be 44° and the direction to N. 10° W.

In order to make a continuous section Hole 2 is taken in reverse order from the farthest end, then the mine section, then Hole 5, are given.

[1]Very extensive drilling on the South Lake has been conducted since 1909, roughly similar to Adventure holes 5, 6 and 7. See appendix.

Hole 6 supplements Hole 5, while 7 parallels part of it. Hole 1 continues the section S.

Adventure drill hole 2. From the 13th level of No. 3 shaft at right angles to the strike and up 23°; the dip of the formation being 44°, we must reduce thickness along the hole by cos (44+23=) 67°=0.92.

1. Feldspathic ophite d 2. 430-527+ (92+)

   At the end the augite has 2-3 mm. mottles, the olivine (altered) and feldspar about 1 mm. each. About 494 it is slightly amygdaloid,—I think, however, a narrow streak,—below at 466 it has more of the porphyritic character, the 1 mm. green feldspar standing out on a red ground, it is more or less speckled and the olivine more conspicuous.

   The seams near 430 at 12° to 15° to the core are presumably at about right angles to the dip following columnar jointing. This is of the same type as 57.

2. Feldspathic melaphyre d 2. 318-430 (104)

   Amygdaloid from 417-430, and speckled beneath.

   Above the base the brown altered olivine specks (1-2 mm.) are conspicuous; the feldspar varies from 0.4 to 1 mm. There are chloritic seams at 15° to core, others at 70°, and amygdaloid seams at 56° roughly parallel to the dip.

3. Feldspathic melaphyre d 2. 275-318 (40)

   Epidotic (altered amygdaloid ? 304-318). About 280-290 fine grained with feldspar somewhat glomeroporphyritic in appearance.

4. Melaphyre 2.217 d 2. -275 (58)
   3.215 d 2. -258+

   This is brecciated with calcite and epidote seams and seamed at about 34° to core. This is also entered in Adventure No. 3 from 215 ft., where it has the characteristic base of this group, in which 1 mm. green feldspars look porphyritic on the red ground. In Adventure No. 4 the altered olivine is given as 2 mm; the feldspar as 0.6 mm.

5. Feldspathic melaphyre with a sometimes *copper* bearing amygdaloid at top
   Adventure 2.0 d 2. -217 (200)
   3.0 -215
   4.0 -217

   At bottom a hard fine grained trap, the 4 feet of 2″ core take a fine polish; size of feldspar 0.4 mm; altered olivine 1-2 mm; feldspar about 153, 1-2 mm. Amygdaloid inclusions begin about 173; *copper* at 192 near base of amygdaloid, epidotic and calcitic to 205; from 205 to 225 more of a brecciated trap separate flow?
   Chloritic joints at 15° to 29° with core.

   In Adventure No. 3 we have the same type; size of olivine and feldspar about 1 mm., very faint; augite mottling at 113 (109) feet up 2-5 mm. across?. the amygdaloid more conspicuous at 178 (170) with calcite and epidote seams, and at 186-190 brecciated.

   In Adventure No. 4 I estimated the size of altered olivine as 1 mm. at 46, 1-2 mm. at 89; the feldspar as only 0.4 mm. at 0-46 ft. There is less amygdaloid in this hole, though it is brecciated about 217.

   A regular ophite of this size should have a well-marked mottling more than 7 mm. across.

Hole 3, at right angles to the strike of the vein, at an angle of 30° up from the 12th level, 400′ E. of No. 3 shaft has had the record given in connection with No. 2.

Hole 4, also at right angles to the strike of vein and at an angle of 27° up from the 12th level, 100′ W. of No. 3 shaft has also been recorded.

In the Mine, the following amygdaloid tops or "lodes" are exposed.

6.	Knowlton lode and foot trap	60 ft.	say (42)
7.	Merchant's lode (51) and foot trap	55 ft.	say (39)
8.	Mass lode (50) and foot trap	110 ft.	say (77)
9.	N. Butler (70) and foot trap	160 ft.	say (102)
10.	Butler (10 to 12) and foot trap	100 ft.	say (70)
11.	Ogemaw (?) and foot trap hanging of Evergreen Lode	300	(210)
		785	540

to Evergreen foot 800 (560)

This feldspathic ophite group also appears in the bluffs, all along, but rarely shows luster mottling distinctly.

Adventure drill hole 5. Begins going down from the Evergreen lode on the 6th level about under this shaft, and 800′ horizontally from it, at a dip of 46°, (i. e., perpendicular to formation). It is thus similar in position to Lake No. 2.

12. Evergreen lode and foot, Feldspathic trap Adv. d 5. 0-40 (60)
2 Lake d 2. 34-185 (83)

A fine grained red feldspathic trap with small amygdules all along.

13. Amygdaloid melaphyre Adv. d 5. 40-108 (68?)
3 & 4 Lake d 2 185-257 (71)

White, very abundant amygdules to 43 then epidotic and calcitic to 49, then a fine grained trap -82, then slightly amygdaloid with epidote and calcite to 82 corresponding to Lake d 2 at 234, then more massive, faintly ophitic at 105.

14. Feldspathic ophite (7 mm.)
Adv. d 5. 108-375 (267)
5 & 6 Lake 257-531 (274)

The amygdules are large white ones 10 mm., and it is either red and white or has an epidotic yellow-gray base. The mottling is rather faint, but appears to have a grain at

152,	155,	170,	182,	195,	200,	205,	210,	217,	225,	228 feet about
2,	3,	6–4,	5–6,	7–8,	5–7,	5–8,	4–5,	2–3,	2,	1 mm. respectively.

At 233 it is specked with epidote and spots of amygdaloid but there was no marked contact and it remains trap to the end. The peculiar faintness and variation in grain is repeated at the Victoria 480-183 and Lake properties. The plagioclase feldspar is less than 1 mm. long.

15. Conglomerate underlaid by brown sandstone. Probably No. 8.

The Caledonia, Winona, probably Forest, etc., one of our chief stratigraphic horizons. It will be noted that there is no conglomerate above it for *at least* 1300 feet and that the beds in that interval are *not* well-defined ophites, whereas in the thousand feet under it sandstones, ophites, and amygdaloid conglomerates are more abundant.

Adventure d 5. 375-419 (44)+
7 Lake No. 2 conglomerate 531-571 sandstone -611 (78)
Just above Mass No. 5. Cf. No. 3 at 450.

The top has an epidotic cement with trap and felsite pebbles and many calcite seams. The seams make angles of 20° and 56° with the core. The bed soon changes to sandstone which *seems* to have fine dips at 50° and at 56° and 58° to 45° with the core. This would mean that it was nearly vertical or horizontal. Seams nearly parallel to the core, probably vertical, are faulted by others more nearly across the core toward the acute angles (reverse faults). It would seem that the west or southwest side is thrown down or to the southeast, and the unusual thinness here as compared with the other places is also probably due to loss on the seams which make it appear to dip at such an angle to the core instead of at right angles as the formation does normally, and the sandstones below.

16. Feldspathic melaphyre Adv. d 5. 419-543 (124)
Lake 2 611-718 (104)

A very little amygdaloid -428, quite a little disturbed with clay slips, etc., which may have cut out part of it. There is copper in this amygdaloid at the Lake. Then massive feldspathic trap (2-3 mm. feldspar as at the Lake), somewhat speckled and finer looking to 543. The Lake does not match well below this.

17. Feldspathic melaphyre Adv. d 5. 543-593 (50)

The amygdaloid is much altered into angular flecks, and the trap is fine in appearance (down to 562, beyond which is all sludge for a ways). Then dark chloritic with bare suggestions of 1 to 2 mm. mottles. The seams at 67° and at 8° to the core are conspicuous. The latter may be parallel to the fissure that runs north near by.

18. Feldspathic melaphyre Adv. d 5. 593-661 (72)
9 & 10 Lake 2. 748-810 (68)

Amygdaloid poor with large angular amygdule forms like that at 543 to 597.

The trap is very light colored in the core, coarse looking; altered olivine is 1-2 mm; feldspar 1-2 mm; iron oxide 1-2 mm; augite does not show well up to 2-3 mm. probably. At 661 an epidotic sandstone dipping apparently 67° against core and charged with copper, may be a clasolitic seam, or be faulted in. There are pronounced seams at 26° to core and the trap the other side looks dark chloritic and mottled 1-2 mm. The very base just above the sandstone is charged with *copper*. The contact dips about 59° with hole.

19. Sandstone and trap mixed. Adv. d 5. 661-679 (18)
(Cf. 9 Lake 718-742), 11 Lake 810-873

The sandstone is yellowish, epidotic, *appears* to dip against core 68°, and contains *copper*. It may be a clasolitic seam, since pieces occur to 679, and it is not found at this horizon at the Mass or Lake mines.

20. Feldspathic ophite (2 mm.). Adv. d 5. 679?-710 41
11 Lake 2 810-873

There are pronounced seams and no amygdaloid at the top, samples of sandstone and trap are mixed together. It is dark, chloritic, and has 1-2 mm. mottles about 695.

21. Brown sandstone and conglomerate Conglomerate 6 Adv. d 5. 710-784(74)
d 6. 56-161(105)
d 7. 290
879-

The dip is practically perpendicular to the hole, Lake 2 making an angle of from 78° to 82° with it, that is what should be expected. It is mainly a dark brown sandstone. The pebbles which occasionally occur are varicolored brown mottled, buff, red felsite and amygdaloid. The conglomerate is largely sandy,—the cement at times epidotic.

The gradual passage to a very unusually pumiceous amygdaloid, while it is liable to be local, seems as a matter of fact to be fairly persistent, being the same also apparently in Holes 6 at 161 down; 7. 174-182. Victoria specimens 1128-1131 feet (?). Cf. Mass 5. 350 ft.

It looks as though the underlying amygdaloid had flowed while the sandstone was forming and wet. In No. 6 this begins at 54 ft. as an amygdaloid conglomerate, then there is a shale with fine bedding within 4° of being at right angles to core, at top black as the Nonesuch, then red, with chlorite on joints and *copper* in a slightly coarser seam, has streaks of green basic sandstone and conglomerate, felsitic conglomerate; there is *copper* also in a pebble at 88 ft.

21a. The real unit of thickness should probably be 21, 22 and 23 which is 137 ft. in Adv. d 5; 166 ft. in Adv. d 6; 156 ft. in Adv. d 7; 147 at the Mass; 142 (Beds 16, 17, 18) in the Victoria cross-cut, as the amount and position of the pumiceous melaphyre is rather variable. The black chloritic shale top appears also to be quite persistent, and the tendency to specks of copper. This gives also a thickness comparable to (235) feet of the conglomerate No. 6 at the top of Winona d 13.

22. Pumiceous melaphyre Adv. d 5. 784-824 (40)

Copper at 808 ft. This is more or less amygdaloidal throughout and at times pumiceous, a regular froth of amygdules.

Cf. Victoria mine cross-cut at 1131 feet.

23. *Brown sandstone,* passing into amygdaloidal conglomerate Adv. d 5. 824-847 (23)

Epidotic to 830, then a deep brown sandstone much jointed and with clay seams dipping 45° to 54° against core.

This is evidently closely affiliated with the sandstone just above, the pumice being a mere interlude, but sufficient probably to show that these beds 710-847 are not a repetition by faulting either of the sandstone just above or that at 1350 to 1458.

Cf. N. Lake 3 at 550

24. Ophite 3 mm.	Adv. d 5.	847-932	(85)
	d 6.	222-302	(80)
	d 7.	231-327	(96)
	Mass. d 5.	353-421	(68)
	Victoria	19.	(98)

The amygdaloid is mainly represented by the amygdaloid conglomerates above. The augite grain at:

875,	882,	892,	899,	908,	915,	922,	932	feet is respectively
2,	3–4,	2–3,	3,	2,	1–2,	1,	$\frac{2}{3}$	mm.

The rate of increase A is about 1 mm. in 16 ft.

The maximum grain 3-4 mm. at d 6. 257 and 3 to 5 at d 7. 290 and 3-5 mm. at the Victoria, agrees well. Cf. also Winona d 13. 62-150. The shale above has probably saved it from disturbance.

25. Ophite, 7 mm. Adv. d 5. 932-1035+ (103+37?)
cf: d 6. 302-400
d 7. 327-403
Mass. d 5. 421-491+
Victoria 20. (106)

Amygdaloid epidotic brecciated 932-940
There are some specks of amygdaloid at 960.
The augite grain at:

960,	965,	980,	1005,	1010 feet is respectively
2–3,	3,	4–6,	7,	3–4 mm.

At 990 it is epidotic seamed, at 1010 yet more seamed, and at 1021 full of laumontitic seams at 12°, 23°, 78° with core, and all the way to 1035, at which point are two feet of epidote. It seems quite probable that part of the bed is faulted out if a yet more important fault does not occur. The grain reaches 7 mm. also at the Victoria, but in Holes 6 and 7 and at the Mass 5 not over 5 mm. are noted. In all the holes signs of disturbances, laumontitic seams, are noted. In this hole there is no bottom contact, but beyond 1035 the grain begins to increase again. If we assume the coarsest grain at 1005 was near the middle, or the rate of increase to it symmetrical, then 40 ft. below should be 2 mm. like 40 ft. above and we should allow at least 30 ft. to the contact, which would make about (140) feet thickness, which it most probably originally was.

But, of course, the same slipping *may* have wiped out any amount more from the section, not represented in 5.

26. Ophite 5 mm. Adv. d 5. 1035-1150 (115+15)
d 6. 400- 517 (117)
d 7. 403- 473+

The augite grain is at:

1053,	1069,	1077,	1085,	1100,	1126,	1135+	
1–2,	2,	4,	3,	4–5,	4,	2,	1-

The rate of increase A is hardly worth computing, the rate is so irregular. This ophite has lost its amygdaloid, and is somewhat irregular in grain; there seems possibly, however, to be some repetition by faulting; a 5 mm. ophite is usually about 100 ft. thick. Part of this should perhaps be credited to No. 25.

Adventure d 6. 400-517 is also a 4-5 mm. ophite, d 7. 403-473 also reaches 3-5 mm; so faintly does Mass d 5. 530-688 perhaps but really the Mass correlations seem to stop with seams that cut Mass d 5. 493 at 35° to 45° with core, probably nearly vertical.

27. Ophite 5-6 mm. Adv. d 5. 1150-1262 (112)
d 6. 517- 627 110

Epidote 1150-1160; then fine grained trap and epidote to 1169; then 2 mm. ophite and amygdaloid inclusions to 1176.

The augite grains at:

	1176,	1182,	1192,	1204,	1212,	1235,	1244 feet shows mottles respectively
about	2,	2,	4,	5–6,	5,	2–3,	2 mm.

The maximum grain (5-6) and rate of increase A 1 mm. in 11 ft. are quite normal. Adv. d 6. 517-627 is about the same size, but the grain was not esimated quite so coarse (4 mm. at 579). The Mass has mottling like it in 5.

28. Ophite (2-3 mm.or 4 mm?)

Adv. d 5. 1262-1350 (88)
d 6. 627- 716 (89)

Brecciated and epidotic amygdaloid, the so-called "Adventure No. 1" lode, fine grained to 1265
Gray epidotic to 1275
Then epidote, quartz, copper?
The augite grain at 1295, 1331, 1348 shows mottles respectively
1–2, 2–3, 1–2 mm.

There are seams (tending to gape!) at 45°, 26°, etc., with the core at 1348.

Adventure 6 while about the same thickness has coarser and more normal grain noted, 3-5 at 681, 3-4 mm. at 686. Faulting or inaccurate observation may account for this.

29. Sandstone and amygdaloid conglomerate; Conglomerate 5?

Adv. d 5. 1350-1410 or -1439 (60) and (29) (89)
d 6. 716-813 (97)

This is massive, more so than the sandstone beds above, with long cores and dips almost at right angles to the core (7°off); no *conglomerate*, but felsite and hematite granules with calcite and laumontite cement. seamed at 20°, 12° etc., to the core. The transition to amygdaloid conglomerate is very gradual, the amygdaloid fragments appearing one by one. This is not unlike No. 23 at d 5. 824-827. From 1428-1434 appears to be a well-marked trap, but there are seams at 26° to hole and since there is no amygdaloid and this is pretty thin for a trap, and the thickness agrees better by counting it as a mere block and the amygdaloid conglomerate below as a continuation of the bed, we do so[1].

Mass 5 does not show this *unless* it is that below Mass d 5. 1391, which would imply something like a 500 ft. fault between the top and bottom of this hole or that.

30. Ophite 4 mm. Adv. d 5. 1439-1529 (90)
d 6. 813- 900 (87)

The trap has amygdaloid inclusions every few feet to 1528 feet. The augite grain at:
1465, 1473, 1477, 1488, 1501, 1509, 1518, 1520, 1525 ft. shows mottles respectively
2–3, 3, 2, 3, 3–4, 4, 1–2, 1, 0.5 mm.,—
though at about 1518 ft. there is a range of 1 mm. grain to 4 mm. grain in the same piece in alternate bands. It is much jointed about 22° to core along 1501-1518 feet.

31. The amygdaloid conglomerate in Adv. 6, is not shown so clearly in 5.

32. Ophite? Adv. d 5. 1529-1619? (90)

Down to 1550 epidotic amygdaloid, then fine grained, dark, chloritic slickensided (at 31° to hole) trap, 1-2 mm. in grain. Adv. d 6. from 900-913 intercalates an amygdaloid conglomerate (Belt 31) but at 948-954 is also about 1-2 mm. in grain.

Adventure drill hole 6. Parallels 5 pretty closely. It is drilled from the surface on the E. side of the Adventure gap near the Copper Range R. R. and just below an outcrop of the Caledonia conglomerate, Belt 15 Adv. above.

[1]It does not look like an intrusion.

20. Feldspathic ophite Adv. d 6. 1-54+ (54)
Amygdaloidal, almost amygdaloid conglomerate 51-53
Gray, massive, fine grained trap.

21. } Sandstone and conglomerate (No. 6) and
22. } Pumiceous amygdaloid Adv. d 6. 54-222 (168)
23. } Black chloritic shales, chlorite on joints 1 foot

A 2 mm. coarser seam charged with *copper* red shale within 4° of perpendicular to core for 20 ft.; then basic green sandstone and amygdaloid conglomerate of greenish gray amygdaloid and white amygdules, with a grayish green sandy matrix.

At about 78 amygdaloid, or green and white red bordered ones to 84. Then felsitic conglomerate with inch pebbles, and epidote and calcite cement, green basic sandstone, and one block of trap a foot long, occasionally a calcite and prehnite cement, and in one case a pebble is impregnated with copper. Then mainly brown sandstone whose dip is nearly perpendicular to core, varying at times as much as 22° from it but oftener 12°-7°. From 161 shading into amygdaloid, apparently alternate streaks of sandstone and amygdaloid conglomerate; between that and 198 is No. 23 a well-marked amygdaloid (which however shows 1 mm. mottles) with a markedly pumiceous base, dip about 20° to core; then a dark sandstone with a speck of copper, then gray epidotic sandstone, then red with gray streaks, full of epidote and red sand grains. At 211 a marbled brown mud often found near the base, then amygdaloid conglomerate bedded almost perpendicular (within 5°) to the core, i. e., dipping 40° to 50°, but jointed at about 59° to core. This passes into an amygdaloid conglomerate with black and white amygdaloid scoria, and a matrix of gray epidotic sandstone or red mud down to 222 ft.

24. Ophite 3-4 mm. Adv. d 6. 222-302 (80)

Amygdaloid 222-224; epidote and *copper* at 232. The luster mottled flashes have less size than the mottles brought out in the drill core pattern. The latter are at:

227–229,	232,	242,	245,	251,	257,	268,	275,	274,	289,	292,	298 ft.
1,		1.5,		2, 2–3,		3, 3–4,		3, 2–3,		3, 2–3, 1–2, 0.5 mm.	

The rate of increase A is about 1 mm. in 17 ft. from the bottom; 1 mm. in 13 ft. from above. Laumontite veins at 292 running at 68° with core.

25. Ophite 3-4 mm. Adv. d 6. 302-400 (98)

There is a trace of amygdaloid conglomerate at top, then black and white amygdaloid to 308, then a foot of epidote; beneath it is specked and fine grained with many chlorite slips as far as 321, and there are numerous bomb-like inclusions of amygdaloid below. The augite grains at:

321,	329,	359,	392 feet are respectively
1–2,	2–3,	3–4,	$1\frac{1}{2}$ mm.

26. Ophite 5 mm. with banded mottling.
Adv. d 6. 400-517 (117)

Marked amygdaloid 400-405. The trap is epidotic, gray and specked beneath, and even the ophitic pattern is brought out in yellow mottles, the size of the mottles varying much in flow bands. This feature seems to be characteristic of this flow; also in Adv. d 5 etc. The increase A from the bottom is about 1 mm. in 10 ft. The mottles at 414 ft. are 2 mm; then finer to $\frac{1}{2}$ mm; then coarser in flow bands up to 2-3 mm. at 414 feet. The mottles are at:

422, 425, 450, 460, 470, 477, 486, 495, 502; 507, 510, 515 ft.
3, 1–2, 3, 3, 4, 4–5, 3, 2.5, 1.5, 1–2, 1, 1-0.5 mm.

27. Ophite 4 mm. Adv. d 6. 517-627 (110)
Cf. Mass d 1. 198-329 *poor match*

The amygdaloid is epidotic and brecciated. The trap is epidotic at 542. The augite grains at:
535, 537, 551, 562, 568, 572, 579, 582, 601, 613, 625 ft. gives mottles about
1, 1–2, 2, 2–3, 3, 3–4, 4, 3, 3, 1–2, 1–0.5 mm. respectively
The rate of increase A is low; from above about 1 mm. in 13 ft.; from below 1 mm. in 20 ft.; at about 613 are seams parallel to core, at 39° and at 68°, often with pink laumontite.

28. Ophite 4 mm. Adv. d 6. 627-716 (89)
Cf. Mass d 1. 329-394 rather *poor*

There is really about 2 ft. of amygdaloid conglomerate at the top and down to 640 there is strongly brecciated and epidotic amygdaloid, and there is 2 ft. of amygdaloid at the base. The grain at:
640, 650, 656, 662, 672, 681, 686, 692, 699, 707 ft. shows mottles respectively
2, ½–2?, 2.5, 2–3, 2–3, 3–5, 3–4, 2–3, 2, 0.5 mm.

A large amygdule has calcite center and heavy chlorite border surrounded by little parallel lines of iron oxide in the rock around, like water lines.

29. Sandstone Adv. d 6. 716-760 (44)
Amygdaloid conglomerate 760-813 (53) (97)

Cf. Mass d 1. 398-430

The sandstone has characteristic, even long cores almost at right angles to the hole varying not over 9°. The jointing at 34° to the core is probably about vertical. It is not disturbed in appearance, and the very gradual transition to amygdaloid conglomerate exactly as in Adventure d 5 seems characteristic. The total thickness is the same. There is some resemblance to 21 and 23, but for one thing the associated traps are much more ophitic, augitic.—Cf. also the sandstones in Mass d 5. between 1391 and 1591
and Mass d 1. 394-430

30. Ophite 4 mm. Adv. d 6. 813-900 (87)
d 5. 1439-1529 (90)
Cf. Mass d 1. 430-443

Amygdaloid 813-827
The augite grain at:
827, 848, 858, 870, 895, 900 feet shows mottles respectively
0.5, 2–3, 2–4, 4, 2, 0.2 mm.
A is about 1 mm. in 11 ft.

31. Amygdaloid conglomerate Adv. d 6. 900-913+23 (35?)
Very epidotic, pumiceous, most of the matrix yellow. The scoria of amygdaloid are dark slate color with white amygdules.

32. Ophite (1-2 mm.) Adv. d 6. 940-961? 21+
The augite grain at 940, 948, 954+ shows mottles
respectively 0.2, 1–2, 1–2, finer
The amygdaloid at the top is merged in the amygdaloid conglomerate and there seems to be a seam at 961 ft.

33. Amygdaloid conglomerate and sandstone Adv. d 6. 961-996 (35)

This begins with amygdaloid conglomerate, with sparse scoria passing into brown and epidotic sandstone bedded at nearly 90° to core (more tnan 83°) down to 967; then almost wholly epidotic sandstone to 997; then to 985 is a pumiceous amygdaloid, and pumiceous amygdaloid conglomerate continues to 996. This is a bed of the same type as 21 to 23, but not nearly as thick, and not in the same association. In the Atlantic Section 16 and other similar cross-cuts amygdaloidal conglomerates occur at several levels under Conglomerate 6.

Cf. Mass d 5. 1543-1591
d 1. 443- 478

34. Ophite, small.

Adv. d 6. 996-1003 (7)

Part is no doubt represented in the amygdaloid conglomerate, but *the mottling is minute, characteristically so.* See Mass, bed 70.

35. Ophite 5 mm.+ Adv. d 6. 1003-1142 (139)

Well-marked amygdaloid 1003-1015.

The augite grain at:

1021,	am. spots,	1045,	1053,	1065,	1068,	1078,	1083,	1093,	1117,
1–2,	0.5,		1,	2–4,	3–4,	5,	4,	4–5,	5,[1]	4,

1127,	1132,	1138 ft.
3,	2,	1 mm.

The rate of increase A from below is somewhere about 1 mm. in 10 ft.; the upper 40 ft. are quite irregular the mottles being only ½ mm. near amygdaloid spots. There are also seams about across the core at 75° to it. Toward the base there are dark gaping, partly chloritic filled seams.

35. Amygdaloid conglomerate Adv. d 6. 1143-1172 (30)

Black and white amygdaloid scoria and red mud cement to 1150, then the matrix is more yellowish and epidotic. Different kinds of amygdaloid and blocks of trap may be recognized.

36. Ophite 5 mm. Adv. d 6. 1172-1240 (68) + (40)

Amygdaloid replaced by the conglomerate above. It is epidotic at top and at 1198. It looks weathered and cracked. The mottling is yellow and shows its nearness to a fault. The augite grain at:

1172, 1178, 1187, 1198, 1208, 1226 feet shows mottles respectively
0.5, 1–2, 2, 2½, 3–4, 5 mm.

The so-called "First Adventure lode" 1252-1288

At this point, Adv. 6. 1240 there is plainly a fault. It *may* only have cut a few feet from the core, but it is probably more important, judging from the jumbled condition of the samples on the south side certainly clear to 1379.

Mass No. 5 between 290 and 491 (the latter apparently the main slip) is full of seams and slips, and therefore Mass. No. 5 can not be correlated. The Mass 5 hole is at 70° and the seams are from 35° to 59° against the core which would mean a possible dip of about 65° to the north. This hole dips 46°. The dip of the sandstone beneath seems nearly parallel to the core at only 20° from it, while the faulting or seams and joints appear to be at right angles to this dip. It is a question whether the apparent dip is not a mere pressure or shearing cleavage. At any rate the abnormal condition is plain. I am inclined to believe that a large strike

[1]Spots on core, reflections in sun about 3 mm., 5-7 mm., from center to center of next.

fault runs near Mass d 5. 491 and Adv. d 6. 1240. The division of the remainder of Hole 6 for 200 ft. into belts is quite uncertain and even more so their distance from the beds above; the ophites below are brown, weathered looking with light gray mottles and have a different aspect from those above.

38. Sandstone Adv. d 6. 1240-1243 and amygdaloid conglomerate 1243-1265 (15)

Cf. belt 33.

39. Ophite, broken up, feldspathic 1-2 mm? Adv. d 6. 1265-1325 (60)

No amygdaloid separable from the bed above. The augite mottles at 1269 ft. are 1-2 mm; at 1282 and 1287 it is a specked fine grained trap; at 1297 is another seam parallel to the core; at 1305 it is trap and at 1315 the grain is 1-2 mm.

40. Feldspathic melaphyre Adv. d 6. 1325-1403 (78)

At 1325 is an epidote and calcite amygdaloid, immediately beneath the trap is seamed at 12° to the core, and the feldspar stands out porphyritically (1 mm. or so) greenish from the red matrix and to 1356 it is a feldspathic melaphyre with 1 mm. feldspars, no mottling. At 1368 there is possibly a fault; 2-3 mm. mottling; near 1379 to 1386 it is much fissured with laumontite joints.

41. Ophite 5 mm. Adv. d 6. 1403-1497 (94)

There is epidote and amygdaloid 1403 to 1410, then fine grained and specked to 1421, somewhat amygdaloidal to 1424, then mottled. The augite grains at:

1437,	1446,	1456,	1458,	1480 ft.	are respectively
2–3,	4–5,	5,	3–4,	2 mm.	

Cf. belt 34.

42. Feldspathic ophite (3-5?) mm. Adv. d 6. 1497-1612 (115)

There is amygdaloid to 1502, perhaps further, and there are lots of slips and it is speckled and epidotic to 1521. The augite grain is at:

1541,	1553,	1571–1577,	1590,	1600,	1612 ft.	
3–5,	3,	1–2,		2,	1–2,	finer respectively

At 1612 feet is epidote seams at 64° come in which may produce faulting.

43. Feldspathic ophite 2 mm. Adv. d 6. 1612-1691 (79)

The grain at:	1628,	1638,	1652,	1671 ft.	is respectively
	1–2,	1–2,	2,	1 mm.	

All the ophites along here are brown, weathered looking, with light gray ophitic mottling quite different in appearance from the rocks above 1240 ft.

44. At 1691 there is epidote and calcite and quite a little copper. This is Adventure No. 2.

Adventure No. 3 is said to have been encountered about (300) feet geologically below in drilling done since.

Adventure drill hole 7 was on the east end of the Adventure bluff close to the gap, and about 75 feet lower than the shaft as well as farther south. The record at the time I looked over the cores was very closely parallel to 5 and 6, Beds 20 to 26.

20. Melaphyre, feldspathic, Adv. d 7. 5-75

Light, greenish gray, hard; feldspar laths less than 1 mm. long; occasional amygdaloid streaks across the core; iron oxides an alteration product from olivine; at 37-39 epidotic with disseminated copper.

21.
22. Together seem as before to make up Conglomerate 6
23.

21. Sandstone and conglomerate Adv. d 7. 75-170 (95)

Begins with one foot of dark shale as in Holes 5 and 6 passing into fine grained (less than 0.1 mm. largely) brown sandstone, whose bedding is practically directly (with 2 and 6) across the core; from 99 down there are streaks of conglomerate, and at times greenish beds and mud bands, near 165 a seam at about 29° to core (that is perhaps about vertical) faults the bedding normally (toward the acute angle)

22. Pumiceous amygdaloid and ophite Adv. 7. 170-213 (43)

Amygdaloid d 7. 170-192

Very pumiceous at first, then from 182-188 a common brown amygdaloid with white amygdules; then to 192 a lot of small amygdules come in.

Trap d 7. 192-211

Specked 1 to 2 mm. ophite.

Bottom amygdaloid d 7. 211-213

In thickness and peculiarly amygdaloid character this matches the other holes so well we may be sure it is not accidental, and I think we may infer that it flowed into the rather shallow water (lake or desert pool) in which Conglomerate 6 was laid down just here. This was perhaps in the center of a desert basin ("bolson") and the mud bands and black shale tops suggest the same explanation. Bed 16 of the Victoria section must have been formed under similar circumstances and may very well be the same bed. Mass d 5. 358-376 *may* be equivalent.

23. Sandstone and amygdaloid conglomerate Adv. 7. 213-226 (13)

Mainly sandstone, with numerous slickenside seams at 59° to the core; toward the base gray and epidotic, and at the very base a foot of amygdaloid conglomerate occurred.

24. Ophite 2 to 5 mm. Adv. d 7. 226-316 (90)

Amygdaloid d 7. 226-231

Black and white

Trap d 7. 231-316?

Specked and epidotic at top; between 231 and 290 gaping chloritic veins. The grain at

231,	252,	265,	277,	290,	305,	307,	311	feet shows
1–2,	2–3,	3,	3,	2–5,	2,	1–2,	1	mm.

mottles respectively, then there is a fine grained epidotic band.

25. Ophite 5 mm. Adv. d 7. 311-403 (87)

The upper amygdaloid is obscured in an epidotic band, but between 327 and 329 is plainly amygdaloid and there are also chloritic amygdaloid spots near 337. The grain at:

337,	338,	346,	352,	358,	363,	375-382,	392,	398,	403	feet shows
1–2,	2–3,	5x3,	3,	3–5,	5,	3,	2–3,	2,	1–2	mm.

mottles respectively. Near 352 are laumontite seams at about 45° to the core.

26. Ophite 5 mm? Adv. d 7. 403-473 (100)

Amygdaloid d 7. 403-415

Brecciated, epidotic for 3 feet, then black and white but in streaks still brecciated and epidotic to 415 ft.

Trap d 7. 415-473

At 420-421 and again near 430 it is gray and epidotic. The grain at:

426, 431, 440–449, 461 feet shows

1, 1–2, 2, 3–5 mm. mottles respectively.

At 461 are seams at about 40° to the core.

Adventure drill hole 1. Near 200 N. of S. E. cor. Sec. 36, T. 51 N., R. 38 W. about 2900 ft. S. of Evergreen lode, i. e., at 44° (2000) ft. beneath it. Dips towards S. 10° E. at an angle of 70° at the beginning, flattening to 60, say on an average 65°. If the formation dips 44°, this would make it cut it at an angle of 71° and at the beginning 66°. Observations on the sandstone at 779 ft. suggest that it cuts it at an angle of ($\tan^{-1}$ 5:2) 68°, which is in agreement. If to get true thickness we multiply by 0.93 we shall not be far wrong. This begins in the same kinds of beds that No. 6 is in at 1691 and were it not for faulting and difference in elevation would probably lap. There were 384 ft. of overburden in No. 1. Its elevation is close to 438 above Lake Superior. 1040 A. T.

48? Feldspathic ophite (5 mm.). Adv. d 1. 385-572=187 (174?)

Much seamed at 7° (veins) 32° conspicuous, nearly vertical? 24.5° to 45°, and veined also at 64.5° to core, parallel to bedding. The augite grain at:

395, 472, 506 feet is respectively

2, 3–5, 5 mm.

between 472 and 506 the seams at 24° and 36° at right angles to others at 64° probably represent the columnar jointing.

49. Melaphyre. Adv. d 1. 572-620=25 (48)

Dark amygdaloid with white amygdules to 576, harder and gray to 581, redder, decomposed; the seams at 20° to 24° and amygdaloid bands at 24° to 36° with core, very conspicuous and at 606 broken up and veined with calcite. About 620 very fine grained.

50. Feldspathic melaphyre. Adv. d 1. 620-704 (78)

Amygdaloid conglomerate, a little perhaps near 620. A sludge near 669, therefore more trap. In one case the seams at 64° to the core are faulted by those at 26°, *the southerly side being thrown down,* if we assume that the 64° seams are really parallel to the bedding. The bed is much veined, specked and disturbed.

49 & 50 are bunched by Meuche quite naturally and perhaps correctly.

51. Feldspathic melaphyre. Adv. d 1. 704-748=41 (38)

There is a feldspathic amygdaloid with pink and white amygdules to 733, then there is a decomposed feldspathic trap which near 745 becomes finer grained and redder, leaving the feldspar more porphyritic in appearance. The seams at the top are at 20° and 52° to the core and nearly perpendicular. Near the base a set at 35° and 55° at right angles to each other are conspicuous.

52. Feldspathic melaphyre. Adv. d 1. 745-775=34 (32)

There is a well-marked red and white amygdaloid to 761; it is then grayer and finer grained, veined (20°) trap to 771.

53. Sandstone and amygdaloid conglomerate. Adv. d 1. 779-866=87 (77)

(Meuche 775-784, and then -934)

Epidotized with specks of pyrite and laumontite passing into a brown sandstone at 783. White seams at 68°, but the dip appears to be steeper, at 59° to 52° against the core. It passes into a conglomerate of dark

amygdaloid fragments and red matrix. In one case lines of white bubbles in mud dip 52°, in another place dips from 35° down to 68° all against the core were noted. The dip from the horizontal is certainly not less than 42°.[1] This is the same type of bed as 29, 33, 38 above, but the associated beds seem more feldspathic. They resemble the beds above Conglomerate 6.

54. Feldspathic ophite 4 mm. Adv. d 1. 866-994=128 (119)
Somewhat amygdaloidal at first, specked and veined.

Several times the seams more nearly perpendicular to the core at 56° to it and probably nearly parallel to the dip are faulted by seams more nearly parallel to the core at 38° or so to it, so that if we assume the latter to be more nearly vertical and the hole we remember plunges to the south, the S. side is thrown down, exactly as in Belt 50. By 902 it is rather massive, 2 mm. feldspar, and there appears a faint mottling. The grain at:

945,	950,	959,	992,	(970 Meuche)	feet is perhaps
3–4,	2–4,	3–5,	2–3,	4	mm.

Toward the base joints are at 21.5° and 68.5° quite persistently, the latter probably parallel to the dip, i. e., at 46° to the horizon.

55. Amygdaloid conglomerate and brecciated amygdaloid. Adv. d 1. 994-1040=54 (50)

There is only a little real amygdaloid conglomerate apparently. 54 & 55 bunched by Meuche.

56. Feldspathic ophite. Adv. d 1. 1040-1279=131 (122)

Amygdaloid, black and white, with vein matter to 1059, then pink and white laumontite to 1106. Trap feldspathic and laumontitic with seams at 37°. At 1131-1138 and 1143 it is epidotic and slightly amygdaloid. The grain at 1204 is probably as coarse as 5 mm. Toward the base it is finer and altered brown olivine, 1-2 mm. conspicuous. The seams at 26°-29° are very well marked, also at 16°, 36°, 58°, 90°, etc.

57. Feldspathic melaphyre. Adv. d 1. 1279-1559=280 (260)

The amygdaloid is well-marked maroon and white with calcite and laumontite to 1299; seams parallel to bedding at 59° and at right angles to it at 29° to the core. Under it it is epidote to 1314, specked and reddish 1316, epidotic to 1322; toward 1335 it begins to look fine grained red and porphyritic and epidotic. The 22° joints are prominent and there is faulting along them. The trap is slightly glomeroporphyritic with 1 mm. feldspar and not mottled toward the base, from 1507 down the brown altered olivine spots become more conspicuous. The joints at 22° respectively 31° and 59° are conspicuous. There are also seams at 15°. The seams at 59° to 51° appear to run with the dip. A bed not ophitic and so thick ought to be an identifiable horizon, *or* is the hole going through this formation quite obliquely?

58. Feldspathic melaphyre. Adv. d 1. 1559-1902=343 (321)

Red and white amygdaloid brecciated to 1591, at base epidote and prehnite with copper perhaps; seams nearly parallel to (at 50° from) core; also at 16°, 31°, 41°, 45° and 51°. The trap below is fine grained feldspathic with chlorite blotches and laumontite seams.

Seams at 18° to 22° are nearly parallel and at 75°. Those at about 15° and 75° occur more than once. The laumontite seams at 36° to core, about vertical, are quite frequent.

---

[1]But see Appendix.

§ 26. MASS MINE. (Pl. XIV, Fig. 52.)[1]

Immediately adjacent is the Mass mine, one of the oldest. Extensive exploration and mining have developed cross-fissures here as in the Michigan and Adventure. These are probably not exceptional. Merely more work has been done here. The map shows a sharp change in strike of the Knowlton and lower beds on this property comparable to that between the Baltic and Trimountain. So far as one can judge this does not equally affect the uppermost beds.[2] With a little intercalation of older data we have a complete section from above the National sandstone. There are numerous maps and plans of the working of this mine on the Survey files, which show particularly well the displacement on cross-fissures. One fissure runs across the formation, dips to the northeast and throws the northeast side to the northwest about 30 feet. Plate XV exaggerates it. (File 15-6.) Explorations have followed along the Evergreen" bluffs, the "Ogima" and "Mass" lodes through Section 6 to the "Nebraska" lode (that is, the Butler) on Section 13 and a conglomerate, the "Nebraska" or "Caledonia" (No. 8) which is exposed in the Lake, Mass and Adventure drilling 1,100 feet southeast, outcrops on the side of the Flint Steel River in Section 12, T. 50 N., R. 39 W.

Here the bluffs overlook the profound pre-glacial transverse valley, largely filled with drift, which the Flint Steel River occupies. Here there is a gap of nearly half a mile without exposures. There is quite a little difference in strike on the two sides and the strike also veers in approaching the valley so that one may suspect that it occupies a fault, or perhaps better a kink or crushed zone in the strata, for there is no indication of any large displacement. At the same time it must be remembered that in passing to the next (the Rockland section) we do pass a gap which we cannot certainly bridge.

Mass Mine Cross-Section (Fig. 52). The location and relation of the drill holes is given in the annual report of the company for 1907, and a cross-section showing somewhat of their relative elevation. The elevations are referred to bench mark probably about 1025 A. T. or 423 above Lake.

The highest hole geologically is 9. Then the others follow in the order: 9, 8, 5, 7, 1, 2, 3, 4, 6. There was a gap between Holes 9 and 8, which are above the Knowlton lode and No. 5, at the time of my examination which I completed from other sources. No. 5 begins immediately below the Caledonia or Nebraska conglomerate, and No. 7 parallels it for 200 ft., there being an outcrop of the same conglomerate not far (about 300 ft.) from No. 7.

---

[1]Plate XIV and Fig. 52 are in envelope. By an oversight the number to Mass drill hole No. 1, occurring between Nos. 5 and 2, does not appear in Fig. 52.

[2]This suggests that disturbance and upheaval were going on at the same time as the lava flows,—an altogether likely supposition.

The dip of the formation is about 43° (B shaft to 14th level); steeper below, due to disturbance?

For correlation with the Adventure holes, see the record of the latter just given.

Mass drill hole 9. At an angle of 45°, nearly at right angles to the beds, near the middle of Sec. 34, T. 51 N., R. 38 W.

The direction is so nearly perpendicular to the beds that distance along the hole may be taken to be true thickness.

1. Ophite, feldspathic 3 mm. d 9. 10-43 (60+)
2. Ophite 3 mm. d 9. 43-105 (62)
   Amygdaloid d 9. 43-59
   brecciated, with black fragments and white cement 43-50, then trappy and chloritic -56, then epidotic 59.
   At 60, 69, 70 ft. the augite grain is
   1, 2, 2-3 mm. respectively, then finer.
   Seams are at 16° to core and less.
3. Ophite 2 mm. d 9. 105-161 (56)
   Amygdaloid, black and white d 9. 105-114
   At 123 and 131 ft. the augite grain is
   1–2 and 2 mm. respectively.
   Laumontite seams at 8° to core, chlorite at 80°.
4. Ophite 2 mm. d 9. 161-224 (63)
   Amygdaloid d 9. 161-178
   with calcite and laumontite amygdules and brownish base to 171, then greenish to 178.
   At 188 and 201 ft. the augite grain is
   1 and 2 mm. respectively, then from 210 distinctly finer. At 207 is a ½-inch calcite-laumontite seam parallel to the core.
5. Amygdaloid conglomerate?
   Not separable from amygdaloid below.
6. Ophite 3.5 mm. d 9. 224-320 (96)
   Amygdaloid and amygdaloid conglomerate with maroon fragments; laumontite, calcite and hardened clasolitic or mud matrix to 237, breciated to 242 16 ft.
   The trap is fine grained with fissures nearly parallel to core.
   At 262, 292, 299, 307, 315 ft. the augite grain is
   1, 3–4, 2, 1-2, 0.5 mm. respectively.
7. Ophite 1.5 mm. d 9. 320-360 (40)
   Amygdaloid d 9. 320-340 20
   Trap d 9. 340-360
   Epidotic to 342, then fine grained ophite 1-2 mm. at 350.
8. Ophite 4 mm. d 9. 360-463 (103)
   Amygdaloid d 9. 360-370
   Calcite, chlorite, prehnite, perhaps a trace of copper.
   Trap d 9. 370-463
   At 405, 415, 434, 452 ft. the augite grain is
   3, 3–4, 3–4, 1–2 mm. respectively.
9. Sandstone d 9. 463-471 (8)
   Light, quartzose, calcitic with epidote seams. Seams across the core, parallel to the dip, are normally faulted by others at oblique angle to it,

which *may* be northward trending nearly vertical faults, throwing the east side to the north.

There are some amygdaloid pebbles so that it passes toward amygdaloid conglomerate near 471.

10. Amygdaloidal melaphyre d 9. 471-527 (56)

Amygdaloid, weathered, trappy at first d 9. 471-513. Fine grained, brecciated, at end epidotic 509; black and white with laumontite and epidote crystals to 513.

Trap mainly d 9. -527

Somewhat brecciated, with chlorite amygdules, somewhat glomero-porphyritic at base.

11. Amygdaloidal melaphyre d 9. 529-598 (69)

Amygdaloid d 9. 527-559

Brecciated conglomerate to 529; epidotic, more or less amygdaloid to 535; red with calcite and epidote toward bottom -559.

Trap fine grained, grows coarser and speckled 1 mm. 589, then an amygdaloid streak, but continues fine grained and brecciated to 598.

12. Ophite, feldspathic 3 mm.+ d 9. 598-795+ 200+

Amygdaloid d 9. 598-608

Full of clasolitic matter, cf. amygdaloid conglomerate. There is also an amygdaloid streak between 676 and 692.

Trap d. 9 608-795

Plainly mottled, somewhat feldspathic; the rate of increase is low like the trap above the Forest conglomerate.

At	613,	621,	635,	650,	750 the grain is
	1,	2,	2,	3,	3 mm.

If, as I suspect, this is the heavy trap just under the old Minnesota Powder house this hole laps Michigan No. 21 (1907), and this is Michigan No. 21, from 0-222.

13. will be Mich. 21		222–327	Powder House vein and foot=105		(75)
14. " " "		327–349	Amygdaloid conglomerate and foot of 13	= 22	(15)
15. " " "		349–379		= 30	(21)
15.A " " "		379–401		= 22	(15)
16. " " "		401–420	Copper bearing amygdaloid and trap	= 19	(13)
17. " " "		420–434		= 14	(10)
18. " " "		434–525		= 19	(65)
			by scaling from old map about (186)		(214)
19. " " "	19	525–464		ab	(46)
20. " " "	19	464–420		ab	(36)
21. " " "	19	420–320	the Rockland or National sandstone	ab	(70)
22. & 23. " "	19	320–0	Mass d 8. 17-119	ab	(256)
24. " " "		the	Calico lode and foot (Mine sections about (100) to (125) Mass d 8. 119-234		
25.			the Minnesota conglomerate. Mass d 8. 234-290 At the Michigan about (64)		(56)

Mass drill hole 8. At an angle of 45° at right angles to the formation about 2640 ft. across the strike from the Evergreen Bluff 470 ft. North, 150 ft. W. of the

S. ¼ post of Sec. 34, T. 51 N., R. 38 W. and is at an elevation of about 1254 A. T. (652.4 Above Lake). From B shaft in Knowlton lode 2654 ft. across the strike and 1898 ft. S. W. along it.

It thus should take from the Minnesota down and should also lap the upper part of the Adventure section and the Michigan Hole 21.

There were 17 ft. of overburden.

22 & 23. Feldspathic melaphyre d 8. 15-119 (104+)

The rock begins in a chloritic massive trap, rather fine grained,—less than 1 mm. There is a seam at 24° to the core, perhaps a vertical nearly northerly jointing. Along about 56-66 there are irregular pseudoamygdules and at 60 a banding at 56° to the core with a seam of clasolite (or amygdaloidal conglomerate) with amygdaloidal specks, below this at 80 is a faint mottling (2-3 mm.) of augite or feldspar, coarser, 3 mm. at 93 and at 113 finer. It may be there are two flows represented but the contact is not well-defined, and generally above the Calico comes a heavy ridge, marking 5 mm. trap of the feldspathic ophite type.

24. The Calico lode and foot, feldspathic melaphyre d 8. 119-234 (115)

Amygdaloid d 8. 119-125

Amygdules green and white, prehnitic and red bordered and white. There are also yellow epidotic spots with chlorite amygdules.

Trap. Feldspathic, mottled, with rare amygdaloid spots, and pink laumontitic seams at 17° to 11°⅓ from the core; also dense green (datolitic) seams.

At 202 there is a 3 mm. mottling on a gray ground which lower down becomes finer and vaguer and under the lens specular iron ore is distinct.

25. The Minnesota conglomerate d 8. 234-290 (56)

From 234-238 a dense mud, marbled in shades of brown, (volcanic?). (This also occurs in the Caledonia and other conglomerates; cf. Adv. d 6. 211) passing into sandstone and amygdaloid conglomerate. The sand grains are mainly less than ⅓ mm. The dip is not less than 76° to 79° against the core. From 249 on is conglomeritic with plenty of sand. The scattered pebbles are generally brown felsite, sometimes white, and the matrix is sometimes calcite.

26. Feldspathic ophite d 8. 290-405 (115?)

Amygdaloid d 8. 290-295

Irregular blotches, with calcite and chlorite.

At 302, 323, 253 to 361

1–2, 3, (faint) 4 to 5 mm.

There are seams at 90° and at 26° to the core, and epidotized bands toward the base at 0° and at 59°. (At 397 some sandstone misplaced by drillers?).

27. Brown sandstone d 8. 405-408? (3) (118)

Dip nearly at right angles to (up to 80°) the core.

Cf. Arcadian 67.

This does not match Conglomerate 6 exactly.

28. Feldspathic ophite d 8. 408-460 (52) (160)

Amygdaloid d 8. 408-417

Well-marked white amygdules on a rather granular ground, with considerable epidote and a little chlorite.

Trap d 8. 417-460

At 427 there is faint 3 mm. mottling, at 443 epidote seams.

29. Amygdaloidal melaphyre d 8. 460-471 (11) (171)

Amygdaloid d 8. 460-468

30. Amygdaloidal melaphyre d 8. 471-504 (33)

Amygdaloid d 8. 471-478

White amygdules with gray epidotic or brown matrix, then trappy and fine grained. (204)

31. Doleritic melaphyre d 8. 504-625 (121)

Amygdaloid d 8. 504-518

It is seamed at 59° and less angles to core; it is amygdaloid in spots to 542, and from 538-564 broken with signs of faults sloping 80° to 73° against core. Then the trap is rather massive, in streaks doleritic with 2-3 mm. feldspar, and at 594 2 to 3 ft. of epidote. (325)

32. Amygdaloid conglomerate d 8. 625-643 (18)

Yellow and buff, much epidotized. (343)

33. Feldspathic ophite 8.643-730 (87)

Epidote at 663; at 706-708 is epidotic again.

At 663, 668, 683, 704 ft. there appears to be a grain of 1, 2, 3-4, 1-2 mm. (430)

34. Amygdaloidal feldspathic melaphyres d 8. 730-909 (179)

From 733-739 is yellow epidotized amygdaloid, then after a little trap, with no defined contact, there is amygdaloid again to 757 with clasolitic streaks of sediment and brecciated spots and white amygdules, then is all rather fine grained specked, quite often fractured at 59° to the core and nearly parallel to it. From 1 to 2 mm. grain, it becomes finer and broken at the base.

35. Feldspathic melaphyre d 8. 921-1100 (179) (609)

Amygdaloid

Brecciated, red, then epidotic d 8. 921-927

Trap d 8. 927-1100

This is at first quite fine grained with minute green feldspars on red ground, like Beds 1-4 of the Adventure cross-section (Holes 2 to 4) above the Knowlton. Toward the center or between 984 and 1033 the feldspar may still (as at 940-984) be 1-2 mm., but there is also a vague 2-3 mm. mottling; toward the base the porphyritic appearance comes out again. At 1091-1096 there is a little red sediment (clasolite). Toward the center columnar joints at 8° to 11° occur.

(788)

This might be Adventure Bed No. 1 or Adventure Bed No. 5, but as we find no correlate to 32 we infer the former or a bed above. There would then be a gap of at least 400 ft. to the Knowton lode uncovered as follows:

36. Feldspathic melaphyre (104)
37. Feldspathic melaphyre (40)
38. Feldspathic melaphyre (58)
39. Feldspathic melaphyre with copper bearing amygdaloid (200)

(402) (1190)

For the beds of the mined zones we have, say:

40.	Knowlton lode and foot trap	42	
41.	Merchants lode and foot trap (Piscatqua?)	39	
42.	Mass[1] lode and foot trap	77	
43-44.	North Butler lode and foot trap	102	
45-46.	Butler	70	
47.	Ogima lode and foot trap	210	
		540	(1730)

Or, L. E. Emerson gives a section for the Ogima bluff:

40-42.	No. 1. Mass mine lode, Knowlton or N. Mass and foot Horizontal	228 at 47° dip	(164)
43.	2.	50	(36)
44.	3.	80	(58)
45.	4. Lode worked (Butler) & foot Ogima mine vein	65	(45)
46.	5.	42	(30)
47.	7. to Evergreen	290	(209)
		755	(542)

According to Dr. C. Rominger (Vol. V, Pt. I, p. 149) a 1400′ tunnel gave at the Mass mine:

40.	Knowlton vein	10-15	
42.	Mass	120′ S. of Knowlton	(86)
45.	Champion or Butler 15-20	90′ S. of Mass	(209)
47.	Ogima 5′-6′ wide (or "Ogema," p. 150).	90′ S. of Champion	(65)
48.	Evergreen 4-40 ft. wide	260′ S. of Ogima	(187)
		760	(547)

At a dip of 43° this thickness should be reduced to about (515) ft.

[48]. The Evergreen and foot is 12 of the Adventure section, and the beginning of the Lake Adv. d 5. 40 (60) (1790)

49. Amygdaloidal melaphyre is 13 of the Adventure section (68) (1858)

50. Feldspathic ophite 14 of the Adventure section (267) (2125)

51. The Caledonia conglomerate (8) is 15 of the Adventure section and 7 of the Lake d 5. 375-419 (44)

(439)

Total below base of Minnesota conglomerate No. 25 (2149).

52. Feldspathic melaphyre is 16 of the Adventure say (124)

53. Amygdaloid conglomerate is 17 of the Adventure and 9 of the Lake; cf. Adventure 19 also (50)

54. Feldspathic melaphyre is 18 of the Adventure and 10 Lake (cupriferous) (72)

Clasolitic sandstone, etc., 97? is 19 of the Adventure? (18)

55. Feldspathic ophite is 20 of the Adventure and 11 Lake (41)

56. Conglomerate (6) is 21 of the Adventure and 12 of the Lake (74)

(818) 379

[1]Another lode has recently been called Mass at times.

Scaling from the 1907 report (840)
Computed below for top of 5, just below it (874)

Hole 5 accordingly would, if it were not for the considerations below, begin not below No. 8, the Caledonia, but No. 6, the next conglomerate below. The drill shanty of No. 5 stood on a conglomerate outcrop. But next below No. 6 come heavy ophites well shown in many sections (at the Victoria and at the Adventure), and the base at the Adventure is peculiarly pumiceous. In both respects beds at the beginning of No. 5 Mass differ from those directly under 6, but are more of the type of the feldspathic group above. Faults shown in the map throw the S. W. side to the S. E. and thus bring the Evergreen nearer Hole 5, so that Hole 5 really begins with No. 52.

Mass drill hole 5, 70° (25° or so from being at right angles to the dip and at right angles to a strike of 38° 45′ E.). Elevation 2.2 above datum 1027 A. T. From B. shaft it is 1102 feet across the strike to the S. E. and 6110 ft. along the same. Add 180 to length of hole to bring it on level with B. shaft and subtract 62 from the distance from the lode gives 1040 ft. which, at a dip of 43° would give (710) feet thickness below the Evergreen lode. To this must be added 180xsin (70+43=67°) =(164) ft. Thus the beginning of Hole 5 should really be some (874) ft. below the Evergreen lode, were it not for displacements and inaccuracy in possible determination of strike and dip. As a matter of fact it begins just in No. 52 under No. 51, about (439) ft. below the Evergreen judging from its associations, the difference (371 ft.) being easily accounted for either by a veering of the strike (371 ft. in 6110 would be not over 3° 30′) or faulting, or both. Depth along hole must be reduced by multiplying by 0.92=sin (70+43°)

52. Feldspathic melaphyre d 5. 28-145 (108+)
Cf. Adventure 16 (124 to 100)
Lake 8

At the beginning epidotic feldspar 2 mm. long, at 112 ft. 2-3 mm. long with strings or bombs of amygdaloid showing that it is not far from the top of the trap. There are frequent breaks at the beginning at about 56° to the core, toward the base seams at 26° and 12° and 78° to the core. Toward the base it appears amygdaloidal with a red base with feldspar laths showing up to 3 mm. long, and calcite amygdules with an epidote border.

53. Amygdaloid conglomerate (No. 7?) d 5. 148-170=22 (20)
d 2. 718-742

At 148 ft. is a hardened red argillite (cf. 56) with a dip against core of 63.5°=tan−2:1 indicating a dip of 46.5°. The colors are maroon to buff; it shades into an amygdaloidal conglomerate with maroon pebbles containing white amygdules and epidotic cement.

This does not appear at the Adventure. Cf., however, Adv. d 5. 661-679 which is probably a clasolitic crack running down from this horizon.

54. Feldspathic melaphyre d 5. 170-222=52 (48)
d 2. 742-810?
Adv. d 5. 543-593

Amygdaloid d 5. 215

Fine grained and chloritic amygdaloid to 194; coarse grained, light gray epidotic amygdaloid with chlorite and calcite amygdules -215. At 215 the feldspar is 2-3 mm. long, then it becomes finer grained and redder.

55. Melaphyre d 5. 222-290=68 (62)
Amygdaloid d 5. 222-236

White amygdules on maroon ground, contact dips about 68° (tan $^{-1}$ 5:2).

Trap. Fine grained, greenish, all full of shear planes that make an apparently coarse texture.

56. Sandy conglomerate (6) d 5. 290-353 41+ (58)
Lake d 2. 879-918
Adv. d 5. 710-784

At the beginning, as often, cf. (25) and (53) is about 1 ft. of fine dark mud above the regular conglomerate. Numerous seams at 63.5° (tan $^{-1}$ 2:1) are nearly parallel to bedding; other dips measure 56°$\frac{1}{3}$ (tan $^{-1}$ 12:8) 57°$\frac{2}{3}$ (tan $^{-1}$ 11:7). All along are occasional pebbles, but much sand.

The interval between this and the conglomerate above (265) ft. or so agrees very closely with that at the Lake (259 ft.) and not badly with that in Adventure d 5 (291 ft.), and the intervening beds can be identified with the Lake very well. So far the section matches the Adventure and Lake.

57. Ophite d 5. 358-421=63 (57)
Well-marked amygdaloid d 5. 358-390=32

The contact 350-353 is well marked with small white pebbles and also black ones, and it remains a *strong* amygdaloid to 376; then comes an epidotic amygdaloid blending into decomposed and seamed trap to 390. This is a distinct ophite.

At 388, 394, 410 ft. the augite grain is
1, 2, 1–2 mm. respectively

Is this Adventure (24) d 5. 847-932? It does'nt at all look like it, and the pumiceous beds 22 and 23 are absent. Cf. the seams at 290 ft. and Adventure belts 38 and 39 at 5. 1243. It more resembles Adv. 22.

58. Ophites and *faults* d 5. 421-688 (245?)
Amygdaloid d 3. 421-429 (to 443 doubtful) (140?)

The rock along here is much disturbed, full of laumontitic slips and seamed at 36° (tan $^{-1}$ 5:7) and 45° (tan $^{-1}$ 5:5) to core, and chloritic at 59° (tan $^{-1}$ 5:3) to core. Near 491 may be a main seam nearly parallel to the drill core, which continued more or less to 561. By 508 it is more settled, a 2 mm. ophite?, but there are a good many pink seams to 530, then more massive faulting ophitic with red specks of altered olivine. Toward the base a set of chloritic seams perpendicular to each other at 63.5° (tan $^{-1}$ 6:3) and 26.5° (tan $^{-1}$ 3:6) to the core may be parallel and perpendicular to the dip. Then the seams at 45° to the core may have a steeper hade, say 25°. There is a faint sign of 3-5 mm. ophite mottling 562-621, but it is clear that no such thickness as (245) feet of undisturbed trap could occur without a much coarser structure than exists. It doesn't seem at all probable that the bed is struck very obliquely[1] and is very much thinner, the indications of dip in it and the beds above and below do not point that way. The alternative is that it is extended by faulting or is a mere fractured aggregate of trap.

From this point on the Mass section does not at all match the Adventure. We cross a great strike fault probably.

59. Amygdaloid conglomerate d 5. 688-689 1 ft.
There is clasolitic red matrix also in the Amygdaloid below.

[1]Confer, however, what is said in the Appendix as to the possibility of southerly dips along here. Were the dips south it would be cut obliquely.

60. Amygdaloidal melaphyre d 5. 689-731 (38)
Amygdaloid d 5. 689-698
Brecciated, and with clasolitic red matter to 712, then slightly more massive but brecciated to about 716; at 712 changes to chloritic amygdaloid, at 726 to 731 becoming red with porphyritic green feldspar as so commonly at the base of feldspathic melaphyres. This is a type of rock found more commonly above 6.

At about this point the angle of the hole changes to 60°. The reduction factor ($\sin^{-1} 60° + \text{dip}$) is probably .97 or so, almost negligible.

61. Feldspathic melaphyre and faults d 5. 731-1182 (440)
Amygdaloid d 5. 731-751
This is gray amygdaloid with coarse 3 mm. somewhat glomeroporphyritic feldspar, specked, broken up and seamed, but getting more massive with hard white seams of datolite or quartz; at 818 there is a faint 1 mm. mottling, from 841 to 908, 2-3 mm., the mottles certainly never reaching 3 mm. It seems to grow finer after 968. Seam at 774-844 at 76° and 63.5° ($\tan^{-1}$ 4 to 2:1) of laumontite at 49°; strong seam at 1125-1136 of chlorite, calcite and laumontite at 22° with core. If, as is quite possible, they are nearly vertical, from the direction of drag, one would say the north side had been moved down. Other seams are at 63.5° ($\tan^{-1}$ 2:1) 51° and 45° ($\tan^{-1}$ 4:4), then 1164-1182 the porphyritic marginal facies once more; at 1182 more sliding and a sudden jump to a 3-4 mm. ophite.
The general type of Bed 61 seems to be rather that of beds above Conglomerate 6.

62. Faulting between 1125 and 1182 especially.

63. Ophite 4 mm.+d 5. 1182-1263 (110+) (80)
Top faulted off.

At 1182,	1220,	1240,	1262 the augite mottling grain is
3–4,	2–3,	1–2,	0.5 mm. respectively.

64. Ophite 4 mm. d 5. 1263-1362 (96+)
Amygdaloid, perhaps amygdaloid conglomerate -1291

At 1319–1343,	1352–1362	
3,	4,	mm.

Then comes another slip fault and a fine grained specked trap.

65. Feldspathic melaphyre d 5. 1362-1391? (29?)
This is fine grained and seamed at about 63.5° ($\tan^{-1}$ 2:1) to core.

66. Red sandstone with tufaceous base d 5. 1391-1418 (20?)
Cf. d 1. 394-430=36 (31)

Dips on the sandstone against the core run from 39° to 68° averaging 52° ($\tan^{-1}$ 1:1, 4:5, 5:3, 5:5, 5:2, 5:4, 5:3). This would mean a dip either of 58° to 68° or else nearly horizontal. In either case it is probably abnormal and due to drop near a large fault, which effect is also seen near 1543. The abnormal thickness of some of the beds above may also be due to abnormal dips so that they were struck transversely. Similar phenomena are found in Michigan holes at a similar horizon in the south part of Sections 14 and 15. At 1413 is the end of the red sandstone and there is fine marbled brown mud. Cf. 56. It shades, by a tufaceous base for the first few feet more into fine grained stuff with prehnite amygdules. If this corresponds to Adventure Belt 29 and Conglomerate 5 it is extra

far away from Conglomerate 6. Has not the hole traversed a more southerly trending fault, which has thrown the east side south?

67. Feldspathic melaphyre d 5. 1418-1494=76 (65?)

The amygdaloid shades into the tufaceous bed above, then becomes dense and dark,—black with red bordered amygdules scattered irregularly to 1444, seams at 59°, both near top and bottom and at 1483 probably nearly parallel to dip. Then a fine grained feldspathic trap to 1480. Then a coarse open amygdaloid, the new flow probably not until 1494.

68. Feldspathic melaphyre d 5. 1494-1543=49 (43?)

Cf. 1. 430-443

Amygdaloid

Marked with red and white amygdules and black matrix -1505

Trap

Massive, toward base finer and feldspar (1 and 1-2 mm. long) appear more porphyritic on a fine ground. Cf. also No. 65.

69. Sandstone d 5. 1543-1591=48 (39)

d 1. 443-478 (to 500) (28)

Very well banded with round grains, unusually like Eastern sandstone. Dips are 54° against core but noted two or three times ($\tan^{-1}$ 6:4) 52°, 56°. A seam about parallel to the core shows a drag in the bedding. Cf. Conglomerate 4

70. Ophite 2 mm. d 5. 1591-1611+ 20+ (48)

d 1. 500-560=60

71. Amygdaloid, black and white.

Then very well-marked ophite, the grain increasing from 0.5 to 2 mm. at the end. The ophitic mottling is very prettily marked in this bed both here and in Mass No. 1. Cf. also Adv. Bed 34.

Mass drill hole 1. A vertical hole 6660.9 feet along the strike S. 38° 45′ and 2906.7 feet at right angles to the lode from B. shaft, elevation-98.7, i. e., about 927 A. T.

The distance at right angles to the strike from 5 is accordingly 1804.7, and to bring them to the same elevation one must add 100 ft. to Mass No. 1. At a dip of 60° to 70° for every 100 ft depth on Mass 5 one must take from 35 to 50 ft. from its distance from Mass 1. Mass 5 1611 may, accordingly be taken at 1805- (225+450) =1135 from Mass d 1; its depth below the top of Mass 5 is 1570 ft. If then we correlate Mass 5. 1611 with Mass 1. 500 we have a dip of 41° $\left(\tan^{-1} \frac{1570-(500+100)}{1135}\right)$ which is plausible enough, as an average dip, though the dips actually noted in the sandstones seem so much greater. In that case the faulting would flatten the dip.

If we suppose d 5. 1611 correlates with d 1. 430 the dip would be 42.5°. If the ophites at the top of d 1. are altogether below 5, as is in some ways likely, the dip would be over 52° which is very possibly true in the particular block in which the top of 1 and bottom of 5 are. The overburden was very heavy, 128 ft., and it must be remembered that the Van Orden brickyard also put down a hole[1] over 200′ in clay.

There is only 550 feet difference along the strike.

Unless we have a dip of over 46° (or faulting) the conglomerate and sandstone of No. 2 should appear in No. 1. The only possible, by no means certain, correla-

[1]Report for 1903 p. 184.

tion is of d 2. 63 and d 1. 590 which is strengthened by the abundance of iron oxide in d 2. 406-585 d 1. 946-1000+. This correction would mean (making no allowance for faults) a dip of only 24° about that noted in the sandstone at d 1. 443. On the whole it seems best to take different factors to get the true thickness derived from the dips in the hole in the sandstones.

Cf. also Adventure 1.

(70?) Ophite d 1. 128-198=70

Gets finer from 2-3 mm. to ½ mm. at 198.

(71?) Ophite 3 mm. d 1. 198-329=131

This is a very pretty, well-marked ophite varying from 3 mm. down to ½ mm.

Amygdaloid probably faulted out.

At 198 it is fine grained, red seamed.

At	206,	217–289,	289,	295,	316,	329 the grain is
	2.5,	1–3,	3,	2,	0.5,	contact

From 217-289 are very many pink laumontite seams parallel to the hole.

It does not seem to be badly disturbed below 289 and the rate of increase A=about 1:15 does not seem abnormally slow so that it is probable that the hole is *not* cutting the formation very obliquely.

? Ophite 2-3 mm. d 1. 329-394=65

Amygdaloid d 1. 329-333

Red, white and green, then not so marked and at 337 massive fine grained trap, but from 339-343 fine grained and amygdaloid in spots (bombs).

At about	350,	360,	376,	382 ft. the augite grain is	
	2–3,	1,	1,	0.5 mm. respectively	

?69? Red sandstone d 1. 394-430

Very red, much faulted; dip if the core is vertical 66° ($\tan^{-1}$ 1.76). It is much seamed and broken; the transition at the base is not a normal but a faulted one. The probabilities are that this is a faulted block of the same sandstone as 69.

Fault at d 1. 433. Cf. Conglomerate 5

68? Trap d 1. 430-443=13

Fine grained, greenish specked trap.

69. Sandstone d 1. 443-478=35 (31)

Seams less disturbed, dips about 26° to 28° (average of 5 observations $\cot^{-1}$ 2.05). Cf. Conglomerate 4?

70. Amygdaloidal melaphyre d 1. 478-495=17 (15)

With small irregular amygdules and white seams at 45°.

71. Ophite 2 mm. d 1. 495-560=65 (58)

Clasolitic amygdaloid or amygdaloid conglomerate -500.

Trap is a very prettily marked ophite, coarsest at 529.

At 508, 529 feet the grain is

1, 2 mm. respectively, and the mottling can be seen clear down to less than half a millimeter. It matches very well with the bottom bed of No. 5. This is so marked an ophite that the slow increase of mottling would suggest more of a dip and that the thickness was really only about 30 ft.

72. Ophite d 1. 560-590=30 (27)

Amygdaloid with pinkish amygdules.

Trap rather fine grained but with mottles up to 1-2 mm. At the base

is a well-marked calcite seam which seems to wipe out the base of the trap and perhaps another bed shown in d 2. 1963 ft.

73. (in d 2?) 44?

74. Conglomerate and sandstone d 1. 590-699=109 (97)
d 2. 63-207=176

Pebbles of fine grained felsites and traps dominate; red rock (augite syenite) occurs, amygdaloid pebbles occur; largely sandstone; bedding in conglomerate 45° in sandstone 70°, 64°, 80° against core, i. e., dipping 26° or less. At the base is a fine flecked or marbled mud just as in d 5. 1413, brown clouded with lighter. We find this also in the Adventure Bed 23, and in d 2. 189.

Cf. both Adventure Belts 23 and 29.

75. Ophite 2 mm. d 1. 699-760=61 (54?)

Amygdaloid d 1. 699-704

Red and white, like that at 495.

Trap

The mottles are about 2 mm. at 723 ft. The increase in grain is abnormally low. Is there not a decided dip close to the fault at 760 nearly parallel to it? At 760 there is shearing and the laumontite crystals filling the seam which is at 68° seem to show drag.

(52)

76. Ophite 2-3 mm. d 1. 760-900= (125)

Amygdaloidal somewhat down to 795; at 830 2-3 mm., then finer grained.

77. Melaphyre d 1. 900-1000+ (120)
d 2. 406-585

Amygdaloid d 1. 900-946

Brecciated, not very amygdaloid, like a conglomerate in spots.

Trap d 1. 946-1000

This is dark, rather fine grained with chlorite seams nearly parallel to the core, granular, massive, with altered olivine and an appearance as though it would run high in iron, in this respect resembling d 2. 406 and d 2. 263-294.

Numbers 74, 75, 76, 77 match fairly well in Holes 1 and 2. In all cases they are greater in Hole 1 by about 25%. This may be due to a difference in the angle at which the holes cut them. The flows beneath the conglomerate (74) all have a rather peculiar character in not being as ophitic as one would expect for their size and in showing plenty of altered olivine.

This character also reappears in the trap in Hole 3, but I do not find anything just like it above or in the Adventure section.

Mass drill hole 2. Vertical, just about in line with Mass d 1 and 6, 661.3 ft. S. 38° 45′ W. along the strike of the Evergreen lode from shaft B. and 3850 ft. from the lode southeasterly at right angles thereto. Elevation (10.3) 1035 A. T., or 109 above d 1, and 943 ft. from it at right angles to the strike. It should therefore lap it unless the dip is more than 49° ($\tan^{-1} \frac{109-19-(0-1000)}{943}$). The dips on the sandstone near the top are from (51.5° to 50°, against the core) 40 to 38.5°. Such dips would make Mass d 2. 0=Mass d 1. 740. This is not possible but the correlation of Mass d 2. 63 with Mass d 1. 590 is quite possible.

Now we find at Mass 2. 171 a white seam making an oblique angle of about 49°, and we also find signs of slip in Mass 1. at 760, so that it seems best to charge the difference to the faulting and suppose that the dip is really about 40°. The reduction factor would then be .77.

The overburden of drift is only 19 ft.

73. Ophite d 2. 19-63=44+
At 34, 44, 62 ft. the grain is
2–3, 1, 0.5 mm. respectively as observed, but the mottles are not plain.

74. Conglomerate d 2. 63-202=139 (107)
Conglomerate—little core—69 ft.
Amygdaloid conglomerate 128-136 ft.
Pebbles amygdaloid and felsite with hematite.
Sandstone at 50° ($\tan^{-1}$ 5:4, 6:5, 6:5) against core, i. e., 38.5° to 40° dip. There is also a seam at 40° to core and oblique to bedding. From 185-189 the red mud filling dips at 41.5°, then grows less and less.

75. Feldspathic ophite perhaps d 2. 202-294=92 (70)
The amygdaloid blends with the base of the conglomerate.
At 218, 263 the grain is 1-2, and 3 mm. faint.
The trap has a peculiar hackly fracture, and much iron oxide; reddened altered olivine and feldspar are conspicuous. It resembles Bed 78 in this respect.

76. Melaphyre d 2. 294-406=112 (86)
Amygdaloid. Brecciated d 1. 294-323. Then there are seams at about 45°, and faulting perhaps, then rather more massive to 353 ft., then a dark amygdaloid with red lines of breccia and small white and green amygdules, with a trace of prehnite and copper, then an irregular trappy amygdaloid to 406 ft.

77. Melaphyre d 2. 406-585=156 (120)
d 3. 26-116
d 1. 946-1000+
Amygdaloid d 2. 406-429
With white and pink amygdules, mottled with calcite and epidote blotches and iron oxides. Altered olivine specks and (probably primary) hematite up to 1 to 2 mm. are a feature; also the fact that it is not plainly ophitic.

Mass drill hole 3. At 49° to S. E. It is 7360.4 feet S. 38° 45′ from shaft B. and 4281.9 at right angles thereto. The elevation is 1024 A. T. (-0.9), i. e., 11.2 ft. below Hole 2, so that to reduce to the same level we must take that much from the running measurements of 2. As they are 432 ft. apart across the strike if we correlate 3.0 with 2. x the dip is $\tan^{-1}\left(\frac{0-11\ x)}{432}\right)$ and if there is no correlation it must be $\tan^{-1}$ $\frac{585+\ -11}{432'}$, more than 53.5°. But there is no necessity for such a dip since we may well correlate: No. 77. Mass 2. 406-585+ (a little)
with Mass 3. 26-116

This would imply a dip of 43° or so, just about at right angles to the hole and very similar to the dip found probable for 2, and only 4° from the somewhat doubtful dip derived by correlation with No. 4. There will then be no reduction factor, the distances along the hole are thicknesses.

Overburden 26 feet.

77. Melaphyre, very olivinitic d 3. 26-116 90+

This is all trap with dark specks of altered olivine, and much iron oxide. There is no notable change in grain. It is very much like the trap in the last two boxes of Mass 2. Cores break square across with a few chloritic seams at only 15° or so with the core. Near d 3. 114 there are seams at 20° and 59° to the core.

78. Melaphyre, olivinitic d 3. 116-305 (189)

Amygdaloid, showing a little copper.

From 114-116 slightly amygdaloid and seamed,—base of the flow above but from 116-134 is a well-marked red and white amygdaloid.

Trap d 3. 134-305

This is at first fine grained, then granular with iron oxide and altered olivine abundant, feldspar 1-2 mm. long, not conspicuous, and augite mottling very vague.

79. Melaphyre, olivinitic d 1. 305-347 (42)

Amygdaloid d 1. 305-311

Not well-defined, somewhat glomeroporphyritic. In the trap, which is like that above, the brown specks are conspicuous.

80. Feldspathic melaphyre d 1. 347-637 (290)

Amygdaloid, poor d 1. 347-351

The trap is coarse, reddish, feldspathic, feldspar 2-4 mm. There are chlorite specks. About 371 are numerous laumontite seams parallel to the core and at 20°, columnar joints?

81. Feldspathic melaphyre d 3. 637-679 (42)

Amygdaloid d 3. 635-669

Poor, contact ill-defined, perhaps about 642 ft.

Trap d 3. 669-679

With white specks, and chloritic and calcite blotches and 2-3 mm. flesh colored feldspar.

82. Sandstone and conglomerate d 3. 679-910 231

Fine grained (less than 1 mm.) mottled a foot or so at top (exomorphic contact); cement calcareous; dips practically at right angles to the core at 74°, 78°, 80° with it; at 686 a red shale, then more conglomeritic. Thence to 806 conglomerate with fine grained felsite pebbles, some amygdaloid, and calcareous cement, then more sandy.

There are occasionally lighter and blotched red and gray streaks with calcareous cement. A dark brown, fine grained sandstone at about 875 ft. makes an angle of 86°, and so do bands of tuff fragments.

The last few feet are amygdaloid conglomerate, and I suspect near the base. The dip can not be over 13° from being at right angles to the hole,—probably much less.

This very heavy sandstone and conglomerate with the peculiarly heavy and coarsely feldspathic trap just the second bed over it should be a well-marked and identifiable horizon.

No. 4 is said to have struck it in the first 10 ft. though none was saved. The dip would then be very nearly 37°, supposing that Mass 3 is within 10° of being perpendicular to the dip. This is fairly close to dips otherwise obtained, the average deviation from right angles to the hole, which is at 49°, being 12°.

This may be conglomerate 3, and probably is, since it can hardly be the repetition of any bed above.

Mass drill hole 4. At 46.5° to the S. E. Located 7351.7 ft. S. 38° 45′ W. of B. shaft and at right angles there to across the strike from the Evergreen lode 5486.8 ft. or 1205 ft. across the strike from 3. Elevation (69.2) about 1094 A. T. The dip (correlating with d 3) is about 47°. The average of drill core observation on a sandstone at 384-541 ft. is about 15° from being at right angles to the core. There may be 4% reduction but not more.

Overburden 73

83. Ophite 2 mm. (44)

Trap d 4. 73 to 117

Begins at the transition from amygdaloid in red seamed trap.

At 80, 91, 102, 113 ft. the augite mottles which are well separated are
1–2, 2, 2–3, 1 mm. respectively.

It is much seamed with laumontite and prehnite and a trace of copper.

84. Ophite 3.5 mm. (92)

Amygdaloid d 4. 117-143

Irregular, brecciated and trappy, with laumontite and red fragments and calcite amygdules, and greenish, maroon or pinkish ground.

Trap d 4. 143-209

At 143, 148, 153, 158, 172, 186, 193, 199
1, 1-5, 2, 2, 3–4, 2–3, 1–3, 1½–0.2 mm. in bands.

The irregularly banded grain in this ophite is notable.

Sp. 3.199 was taken for section.

85. Ophite (29)

Amygdaloid d 4. 209-233

Very well marked, brecciated, red and white (like that at 117 ft.) to 226 ft., then about 231-233 sediment and amygdaloid conglomerate or clasolite, seams at about 35° to core ($\tan^{-1} 5{:}7$) brecciated.

Trap d 4. 233-238

Presumably a gush of the underlying flow.

86. Ophite 3.5 mm. (87)

Amygdaloid d 4. 238-247

Pink and white, laumontitic

Trap d 4. 247-325

At 260, 264, 272, 280, 309, 316-325 ft. the grain is
2, 2–3, 3, 3–4, 1, black aphanitic respectively.

87. Ophite 3 mm. d 4. 325-384 (59)

Top is a red seamed breccia from 325-370

At 332, 359 the grain is
1–2, 3 mm., then finer.

88. Sandstone and conglomerate d 4. 384-541 (157)

Sandstone with angles against core 67°, 74°, 67°, and white seams (nearly perpendicular). At about 449 feet a breccia seam. It is quite massive brown, with long cores—at about 472 is a foot of conglomerate but it is mainly sandstone to 513, then there is a conglomerate with a variety of pebbles (beside felsite, labradorite porphyrite, quartzite, light pink, *granitic*, dark and amygdaloidal.) It passes then into amygdaloid conglomerate at about 522 ft. with black and white amygdaloid scoria and maroon mud matrix full of fine white seams at an angle of about 70° to the core parallel to dip?

89. Ophite 8 mm. d 4. 541-716=175 (175-to 164?)

Amygdaloid d 4. 541-549

Below 549 is fine grained and brecciated, with amygdaloid spots.

Trap d 4. 549-716

At 586, 621, 634, 644, 656–664, 676, 682, 690, 706, 716 ft.

3, 5–6, 8, 7, 6, 3–4, 3, 3, 1, 0 mm.

The rate of increase A is about 1 in 11 ft. or so, quite normal for an ophite. It might pass for the Mabb ophite.

90. Ophite d 4. 716-760+ 34+

Amygdaloid d 4. 716-727

With some clasolitic matter, verging on amygdaloid conglomerate.

Trap d 4. 727-760

Specked to 74°.

At 748, 760 feet which is the end of the hole the grain is 1–2, 2–3 mm. respectively.

Hole 4 is characteristically ophitic as Hole 3 is not.

Mass drill hole 6. At 45°. Location 7737.8 ft. S. 38° 45′ W. of B. shaft and at right angles thereto across the strike 6.306.4 feet. Elevation (42.2) 1067 A. T. It is accordingly 822 ft. from 4 and about 27 feet lower. No. 6 starts in with a 3-4 mm. ophite which breaks nearly perpendicular and parallel to the core which might be No. 90 perfectly well and this would allow a dip as flat as 53°. Flatter than this it can hardly be. No reduction factor seems necessary.

Overburden 52; first core at 74 ft.

90. Ophite d 6. 52 to 92 to 106 (40) (to (56)?)

Trap 3-4 mm. grain? breaks parallel and perpendicular to core.

At about 92 ft. it is finer with amygdaloid spots.

At 106 ft. the grain is 3 mm., and is somewhat seamed perpendicular to the core, and at 23° and 20° and 57° to the core, those at about 20° looking like bedding.

91. Melaphyre d 6. 92-135

Seamed, slightly amygdaloidal. About 132 ft. more so.

Seams at 24°, 8° and 20° to core.

92. Sandstone and conglomerate d 6. 135-168 33

Small felsite pebbles with calcite cement.

There is also much dark red sandstone dipping 70° against core. There is also a seam dipping in the same sense relative to the hole, but at only 24°, 18.5°, etc.

At 156-159 ft. the dip is 51° against the core with joint seams perpendicular thereto.

In case of a seam dipping the same way against the hole as the bedding but more nearly parallel to hole there seems to be a down drag of the upper side.

93. Melaphyre d 6. 168-192

Amygdaloid d 6. -178

Fine grained, seamed, and prehnitic.

Trap is fine grained and decomposed.

From 192-195 is part Jacobsville sandstone, part Keweenawan sheared together.

94. Jacobsville and Eastern sandstone d 6. 192-622

This is a friable sandstone nearly white to light pink, with the grains more exclusively quartz, usually ½ to ⅓ mm., more rounded and larger

than in the Keweenawan sandstone; the dips against the core usually about tan — 1 51° probably about horizontal at 225 ft. 50° to 38°, at 262 ft. 38°, or 35°, seams parallel to core are perpendicular to dip. At 302-393 32° quite persistent (probably 13° to the S.), at 393-478 51°, at 495 apparent dip makes angle of 74° with core, say 29° dip, and is faulted by seam nearly at right angles at 51° to core, a normal fault; at 598 to 622 at 51° with seams at 26°. Probably the last part dips about 6° to the north.

The two conglomerates 88 and 92 might perhaps match those close under the Lake lode and 82 or thereabout, might be the Lake lode. Cf. also Adventure 29.

§27. MICHIGAN AND ROCKLAND. (Pl. XIV, Figs. 52 and 53.[1])

Beyond the Mass is a wide valley occupied by a transverse river, the Flint Steel, which runs in a pre-glacial gorge cut down like Portage Lake through a mantle of Paleozoic sediments now removed. It is overlooked on the east by Caledonia Bluff (named after an early mine). For half a mile there are no exposures. On the south side of this bluff is a conglomerate named after it. There is a considerable swing in the strike just here and (since there may well be a displacement) the possibility of an error in correlations. Moreover, a slide fault such as is known to exist in the Minnesota mine might well stop or change the amount of its displacement here so that one part of the section might match closely and another part be displaced. At and near Rockland, there are, however, exposures frequent enough to make up a fair section and this is being supplemented by S. Brady and C. M. Haight, respectively, the able agent and engineer of the Michigan mine. And as the Nonesuch sandstone and the felsite is exposed we can patch together a section of all the higher beds down to Bohemian Range group.

Freda Sandstone. Base exposed in Section 4, T. 50 N., R. 39 W., extending thence north ten miles to Ontonagon. The dip in Section 4 is 40°. Along shore the dip is slight. The thickness can only be guessed and Chamberlin's remarks on the building out of sandstones may apply[2] judging from the Montreal and other sections. However the thickness is not less than (5000)

The base has holes after stellate groups of crystals like the Fontainbleau calcite pseudomorphs.

Nonesuch Group. Greenish black chloritic sandstones or fine grained conglomerates with the red and green granules not much more than a millimeter across. (400)

---

[1]Plate XIV and Figs. and 53 are in envelope.
[2]Geology, Vol. II, pp. 192 and 262.

COPPER HARBOR CONGLOMERATES. The total section from here to the felsite is very much less than on Black River and the Porcupine Mountains and one is tempted to suppose that the Lake Shore traps have dropped out entirely. They seem to thin also in going from the Mount Bohemia focus to Portage Lake. In that case one conglomerate may include the Outer, the Middle and the Great Copper Harbor conglomerates. There is, however, a covered interval in which the Lake Shore traps may occur. There is about, however, of exposed coarse conglomerate (10 inch pebbles). (75)

Dark mottled sandstone. (75)

Conglomerate 850, dip 44° or 42°, on Section 8 in the railroad cut. (600)

Some old maps indicate on unknown grounds (probably old trenches) a narrow band of (Lake Shore?) trap, of thickness not over. (200)

—below the railroad exposure, followed by as much conglomerate more. (600)

This would reduce the gap at present unexposed of about (1000) feet to only 200. (200)

This 1,750 feet is not unlike that found on the Montreal River at about an equal distance from the Porcupine Mountain or Chippewa felsite.

ASHBED AND EAGLE RIVER GROUPS. This is followed in Section 8, T. 50 N., R. 39 W., along the railroad track by a rather imperfect succession of beds of Ashbed type as follows (cf. Black River 6 e)

1.	Conglomerate basic and sandy		
2.	Amygdaloid		(120)
	Trap		
3.	Possibly all amygdaloid conglomerate		(88)
	Amygdaloid conglomerate	(30)	(128)
4.	Fine grained trap with flow lines		(30)
5.	Amygdaloid conglomerate		(50)
6.	Fine grained trap (Ashbed type?)		(20)
7.	Amygdaloid conglomerate		(50)
8.	Amygdaloidal porphyrite		(20)
	Trap with flow lines, felsites		(44)
9.	Amygdaloid conglomerate		(30)
10.	Labradorite porphyrite, 4 mm. feldspars		(40)
11.	Banded felsite porphyrite		
	covered and		
	Quartzose amygdaloid and		
	fine grained black trap like the Minong		(140)

12. Amygdaloid conglomerate of "Ashbed" type with red sediment and marked amygdaloid "bombs" (28) (700)

Estimates would make this total 1,200! Probably there are small, overlooked unexposed gaps.

Next comes the Chippewa felsite, which also on Section 9 shows this series of fine grained traps and amygdaloid conglomerate over it. (See Ss. 19655 to 19660 not all of felsite.)

Its thickness is there	(500) to (350)
Total Ashbed group	(2200) to (1050)

CENTRAL GROUP

Close below comes a 3 mm. ophite

Then a conglomerate with 8 inch pebbles, some basic, many felsite. This conglomerate can be traced in Section 8 very well, also in Sections 9 and 10. I identify it with the Allouez No. 15. Scattered in the south part of Sections 8 and 9 are outcrops of ophites and amygdaloids which partly, but not continuously, fill in the gap to the Rockland Creek section of about 2000 feet or (1375)

It is noteworthy that this belt which has been the scene of much work in Keweenaw County has hardly been touched here. Then follows a nearly continuous section of Rockland Creek which was once trenched out and made continuous by B. F. Chynoweth. Of this creek a transit survey and careful section was made by P. S. Smith and W. V. Savicki (File 14-18, Ss. 19412 to 19459). The dip is 40° to N. 32 W. An abstract is as follows:

Down to first conglomerate (250)

Conglomerate down 3 feet of sandstone, then felsitic and at base amygdaloid conglomerate. Near the north line of Section 11, dip 40° on the creek, also 3000 feet north of the south quarter post of Section 10. It is also said by Fuller in 1897 to have been exposed a few feet northeast of the south quarter post of Section 9.

Total distance of base from base of Conglomerate 15 in Section 10 at 42° dip, breadth 2400, or thickness (1650)

This conglomerate is identified as the West Minnesota conglomerate in the older maps. (See Fig. 52.) It is rather coarse and just above it is a very fine grained compact, dark trap of the Minong trap type, somewhat suggestive of the Ashbed group. Below it the Rockland Creek section continues, showing laumontitic and black traps and blue amygdaloids. The following is the record:

Second important conglomerate of Rockland Creek section.		
Base is below base of conglomerate above		(870)
Base is below base of conglomerate	(15)	(2920)

The creek section continues for about 700 feet but on a rising grade so as to expose only about (File 15-31 and 14-18) (435)

	Talus			
50.	Breccia, light matrix, dark trap and amygdaloidal fragments, considerable epidote	112	(82)	
49.	Moderately coarse grained trap with quartz, feldspar and epidote, like No. 48 except coarser	10	(6)	
	Talus	104	(70)	
	Same as No. 48	5	(3)	
	Talus	102	(70)	
48.	Very fine grained dark trap, very compact. Minong type	48	(32)	
	Talus	23	(13)	
	Very fine grained dark trap, much jointed, fragments angular, evidences of slipping. Exposed in pit overlying conglomerate			(294)
	Conglomerate, rather coarse	60	(45)	
	Talus	10	(7)	
47.	Fine grained brownish amygdaloid, amygdules filled with quartz, calcite and epidote	20	(12)	
	Talus	113	(79)	
46.	Moderately coarse grained amygdaloid, amygdules filled with quartz, calcite and some prehnite; carries some free copper	58	(37)	
	Talus	23	(14)	
45.	Moderately fine grained greenish trap, with quartz, feldspar, and augite recognizable	10	(6)	
	Talus	23	(14)	
44.	Dark amygdaloid, amygdules filled with quartz, calcite and epidote, some cavities show fine quartz crystals	50	(30)	
38.	Moderately coarse grained greenish trap. Contains some laumontite			
38A.	7-foot band of amygdaloid. Trap weathering to a conglomeritic appearance. Not persistent and lies about the center of belt No. 38	105	(56)	(300)
37.	Light grayish green amygdaloid trap, amygdules filled with quartz, calcite and prehnite. Shows traces of free copper. Some slickensiding	103	(65)	
36.	Light grayish trap. Foot contact more amygdaloidal. Amygdules often showing fine crystals of quartz	13	(7)	
35.	Moderately coarse grained brownish trap. Much iron stained	60	(33)	
34.	Very fine grained dark greenish amygdaloidal trap. Amygdules filled with quartz, calcite and epidote	47	(33)	
33.	Coarse grained reddish diabase. Much iron stained. Becomes more amygdaloidal near hanging base	5	(3)	
32.	Reddish amygdaloidal trap with rounded amygdules filled with epidote and calcite. Matrix shows augite needles	28	(17)	
	Talus	28	(12)	
31.	Light colored greenish amygdaloid becoming more trappy a few feet from foot contact. Amygdaloid filled with quartz and calcite	23	(15)	

30A.	3-foot band of much decomposed trap, which weathers to a conglomeratic appearance	5	(3)	
30.	Moderately coarse grained brownish trap, showing some small amygdules filled with quartz, calcite and epidote	35	(15)	
	Talus	60	(40)	
29.	The 3 feet next to foot is an amygdaloid. Amygdules filled with calcite and laumontite. The bed then merges into a very fine trap	110	(77)	(320)
28.	Fine grained amygdaloid gradually merging into a trap. Amygdules filled with epidote and quartz	25	(17)	
27.	Very fine grained dark trap wih a one-half inch brownish band running through it	38	(22)	
	Talus	230	(165)	
26.	Dark brownish green amygdaloidal trap with moderately fine grained irregular amygdules filled with epidote and quartz.	5	(4)	
25.	Weathered specimen of amygdaloid fom dump presumably from pit which overlies conglomerate. None found in place. Amygdules filled with epidote and calcite	15	(10)	
	Conglomerate rather coarse	32	(23)	(297)
24.	Moderately fine grained brownish amygdaloid. Amygdules filled with epidote and calcite	28	(20)	
	Talus	80	(58)	
23.	Fine grained, compact, dark greenish trap with 6-inch band of amygdaloid near center, walls indeterminate, reddish amygdules	93	(63)	
	Talus	10	(8)	
22.	Fine grained greenish trap with small irregular amygdules filled with quartz and calcite	45	(23)	
21.	Same as No. 16	8	(6)	
20.	3-foot band of trap merging into No. 21	3	(3)	
19.	Amygdaloid	95	(67)	
18.	$1\frac{1}{2}$-foot band of trap merging into No. 19	2	(1.5)	
17.	Fine grained greenish amygdaloid often merging into trap. Amygdules filled with calcite and laumontite	8	(4)	
16.	Moderately coarse, brownish amygdaloid. Amygdules filled with laumontite. Similar to No. 14			
15.	Rotten, brown trap, showing augite, feldspar and quartz	16	(10)	
	Talus	15	(4)	
14.	Moderately coarse grained brownish amygdaloid. Amygdules filled with laumontite	5	(4)	
	Talus	35	(25)	
	South line of northeast $\frac{1}{4}$ of Section 10, T. 50, R. 39			
51.	Coarse grained diabase, showing crystals of feldspar, quartz, and augite and considerable epidote	10	(7)	

52.	Light greenish amygdaloid, irregular amygdules filled with quartz and calcite	35	(25)	
53.	Rather decomposed, dark greenish diabase. Much iron stained on weathered surface	25	(18)	
	Talus	20	(15)	
54.	Rather fine grained, dark gray amygdaloidal trap. Amygdules filled with calcite and laumontite	5	(3)	
	Talus	5	(3)	
55.	Decomposed brownish trap. Similar to No. 15	40	(27)	
56.	Very fine grained dark brown trap. Much iron stained on weathered surface	30	(24)	
57.	Moderately coarse grained. Rotten amygdaloidal trap with small amygdules filled with calcite and laumontite			
	Talus	7	(5)	(435)

The next conglomerate reported is one exposed by a well in Agent Brady's yard in Section 15, on the outskirts of Rockland. (See map, Pl. XIV.)

Base below base of last conglomerate (1480)

Above the heavy 7 mm. feldspathic ophite in which drill hole 21 begins this is probably not more than (750)

This 7 mm. ophite is a rather heavy bed which makes a continuous ridge on which the Powder House stands and we may refer to it as the Powder House ophite. It runs continuously from the drive up to the mine to the southeast corner of Section 10. Here it seems to be slightly displaced to the south, but then may be followed practically to the center of Section 11.

Old and new sections are frequent from below this point. Taking the mine records and my notes of drill hole 21 we continue.

1. Powder house 7 mm. ophite, faintly mottled, one epidote "bomb" with some fine copper at 20 feet, from 44 to 105 3-8 mm. mottles, at 120-138 about 7 mm. faint and irregular mottles, then growing finer. The top of drill hole near top of bed.
   Probably Amygdaloid (18)
   Trap d 21. 0-222 (162) (180)
2. Feldspathic ophite (78)
   Amygdaloid Powder House vein d 21. 222-234 (10)
   Brown and white, irregularly streaked
   Trap d 21. 234-327 (68)
   Feldspathic, very faintly ophitic, about 4 mm. at 290, growing finer
3. Amygdaloid conglomerate and amygdaloid d 21. 327-349 (16)
4. Amygdaloid d 21. 349-360 (8) (22)
   Trap d 21. 360-379 (14)
   Fine grained, speckled

5. Amygdaloid d 21. 379-400 (15) (21)

With sediment dipping at a little more than 45°, also (56) epidote and copper, especially about 393 for five feet sprinkled through this and the trap

Trap 400-408 (6)

6. Amygdaloid conglomerate? d 21. 408-430 (16)

7. Trap d 21. 430-525 (70) (86)

Specked to 430, coarsely amygdaloidal to 458, then feldspathic, faintly ophitic, seams dip about 50°.

8.

Amygdaloid d 21. 525-534 (7)

Cold gray epidotic, carries a few specks of copper. Here we pass to the record of Hole 19 from the 12th level horizontal 520-504

Hole 19 record scaled, which agrees substantially with an old record by George D. Emerson.

Trap d 19. 504-462 (33) (40)

9. Ophite

Amygdaloid d 19. 462-456 (3)

4-foot vein carries some copper

Trap d 19. 456-416 (29) (32)

10. Rockland[1] or National sandstone d 19. 416-306 (80)

Base below base of last known conglomerate about (1100)

The Michigan mines steepens in dip in the A and B shafts from 46° 36′ at the surface to 55° at the 17th level. From the 10th to the 12th it is 52°, thus the Bee shaft carried down at an even slope is in the hanging at the 12th level where the drill hole starts. The "Branch" or Rockland vein,—a fissure—approaches the "Calico lode" and is now being developed at the Bee shaft. At the north end near the C shaft it is 135 feet from the "Calico" but meets it to the south and downward, at the C shaft about the 6th level and crosses it and is in the foot, and is full of small faults that throw the east side south. The chutes of better rock are said to pitch toward the Ontonagon River.

The National sandstone and Minnesota conglomerate have been traced continuously in mine workings and exposures across from Section 15 into Section 16, T. 50 N., R. 39 W., and across the railroad track (File 15-1) where the dip is about 53.5° to N. 28.5° W.

The last section between them close to the Creek shaft toward the river is:

National sandstone	60
To amygdaloid	90

[1]Rockland seems the older name, being used in George D. Emerson's 1859 report. But Broughton's map uses the term National sandstone, from the National mine, and that is more current.

To another amygdaloid	74
To epidote	112
To amygdaloid	100
To Minnesota conglomerate	134

In the north end of the adit at the Bee location we have this section (File 14-41). The strike is N. 20 W. The cross-cut tunnel is near north.

11. Trap 0-246 at right angles to strike from north end of tunnel.
At 115 seams 2″ wide, dip 40° drifted on
Amygdaloid 246-251, width 5′, dip 49° ("North Amygdaloid")
With heavy copper, now worked.
Trap 251-327

12. Amygdaloid vein (to test pit?) 10 feet, dip 36° 327-337.
Calico lode? 368-374. Amygdaloid vein 8 feet, dip 55°.
Trap with numerous seams.

At 400, 8-inch seam parallel to strike, dip 37°, at 430 9-inch, dip 37° E. of N., at 443 9-inch, dip 65° to N., at 457 8-inch, dip 55° to E. of N., at 463 6-inch, dip 34° to W. of N., at 472 4 to 6-inch, dip 35° just parallel to dip of formation.

13. Beginning of south end of cross-cut tunnel 520-526

Along this there was a drift for 310 feet on the so-called "contact" or "south" vein. The adit into it was 165 feet farther west and showed the following bed:

14. Minnesota conglomerate 31
Sandstone 57
Foot and drift to a total of 200 feet.

Thence to the north end of the south adit on Section 15 (see Pl. XIV) is about 1250 feet by (File 15-26) (920)

Allow Beds 15 to 28 to correspond with the Mass section. (Fig. 53)

29.	Black trap at N. end		(1090)
30.	Mass lode (presumed) 0-10	(220)	
	Dip 46°, carries copper		
	Dense gray trap 10-380		
	6-inch parting, carrying copper with 44° dip		
	18-inch parting, carrying copper with 35° dip		
	3-inch parting, carrying copper with 32° dip		
	Then brownish and gray, "felsitic",—i. e., very fine grained		
	Below Minnesota conglomerate		(1310)
31.	Butler lode (presumed) 380-425 (Cf. File 15-26)	(57)	
	Trap 425-485		
	See Plate XIV. Upon this there was considerable work done.		(1367)
32.	Amygdaloid d 19. 485-492 (Ogima lode?)	(80)	
	Trap d 19. 492-605		(1447)

Early maps show conglomerate 50 paces north and a conglomerate 100 and a lode 830 paces south of the southeast corner of Section 15. The uppermost of these should come close below this section, and if Bed 31 is the Butler lode we should have (cf. the "Adventure" section).

33.	Evergreen lode and foot, Adventure 12	(83)	(2030)
34.	Amygdaloidal melaphyre	(71)	(2101)
35.	Feldspathic ophite (7 to 8 mm. faint)	(267)	(2368)

36. Caledonia conglomerate (Adventure 15) No. 8 probably underlain by brown sandstone. It will be noticed that here as there, no *known* conglomerate comes above it up to No. 14. But on the other hand there are unexplored gaps and the "Butler lode" may not be such. The distance as above given is greater than at the Mass (2149) but not much in such a patched section. A cross-fault may reduce the unexplored gap.

Below, the section is more or less exposed in bluffs on Sections 13 and 14 and on a hill known as the "South" or "Third Brother" on Section 21-22, south of the railroad. Owing to the cross-faults, however, the correlation is not sure. On Section 13 the crest of the bluff is made of a heavy 5 mm. feldspathic ophite with greenish bands that dip 62° to 66°, but underneath comes a narrow belt of red sandstone and shale with well-defined 33° dip, then amygdaloid and faintly feldspathic ophite with 40° bands to the base near the railroad track.

The section is important as indicating flat dips. The feldspathic character is that of the Evergreen bluffs. The distance from the Minnesota conglomerate near the north quarter-post of Section 14, 2400-2900 feet, would indicate that the section exposed must be some (1700) feet below and near the top of the Bohemian Range group. At a dip of 35° the section would be continued by that of drill hole 22. The heavy sandstone conglomerate bed of Michigan d 22. 383 feet, must probably be Mass-Adventure bed 15 or 21. But the bed above can hardly be Adventure 14. Adventure beds 19 and 20 in Hole No. 5 at 661-669 (which also contain copper) may better be compared. But if Michigan d 22 does skip the Caledonia conglomerate No. 8 it must be very close under it, perhaps immediately. This we assume. At any rate it seems safe to assume that Michigan 22 is in the same general position geologically that it is topographically. Just where it is and just which side of the fault shown on Plate XIV near which it lies is a question. Drill hole Michigan 22 is supposed to be about 1865 feet south of the "Butler" lode as exposed near the quarter-post between Sections 14 and 15 and about 3500 from the Minnesota conglomerate. The Butler lode is, however, thought to be thrown 400 feet by an oblique fault which produces only 80 feet displacement at right angles to strike, and a fault line (see Pl. XIV), which runs nearly north and south and throws the Powder House 7 mm. Bed 1 to the south on the east side, must run near the hole and may disturb the correlations. Still other faults have been recognized by Haight. The elevation is (by barometer from bench mark) 410 above Lake Superior. It lies south of the railroad track and west of the road in Section 15. The dip of the hole is to S. 45°, the apparent dip of the beds at the surface (for it starts on the north side of a low outcrop) only 35°. Compare the flat dips found in the lower Mass section. The record is as follows:

MICHIGAN DRILL HOLE 22.

37. Glomeroporphyrite d 22. 1-35 (35)
Cf. Mass 52
38. Amygdaloid d 22. 38-45 with copper at 40
Trap with amygdaloid spots d 22. 39-54
39. Glomeroporphyrite (104)
Amygdaloid d 22. 54-67

Dark
Trap d 22. 67-159

40. Clay seam. Fault? d 22. 159-½-168-½ (Adventure 15 cut out?)

41. Melaphyre (Adventure 16) (54)
Amygdaloid d 22. 168-½-198
Trap d 22. 198-214
Broken

42. Feldspathic ophite (Adventure 17) (69)
Amygdaloid d 22. 214-235
Trap d 22. 235-283
1-2 mm. at 236-266; but little core, considerable copper from 266 down to 283

43. Conglomerate (No. 7?) (5)
Felsitic d 22. 283-288

44. Ophite (Adventure 19 and 20) (100)
Trap d 22. 288-378
Reddish, full of calcite, with specks of copper, at 296-299 a vein of calcite without copper, with chloritic bombs, 1-2 mm. green feldspars, and chlorite amygdules (and the core jams badly, largely sludge) toward the base and near the conglomerate, perhaps amygdaloid, very chloritic, with numerous laumontite seams at 31° and 50° to the core; occasionally 1-2 mm. mottles.

45. Conglomerate and sandstone (Adventure 21?) (62)
Upper contact at 45°, conglomerate 338-388 with copper, at 378′ 6″, then brown sandstone 388-400 with dip at 64° to core A seam at 79° to core shows other seams parallel to the core but faulted by it and thrown into the acute angle. Assuming that this angle with the core is due to a flatter dip than that expected we may infer an upthrust or if the seams are like the Central mine-vein that they have been similarly displaced.
Amygdaloid well-marked gray d 22. 400-
No. 23 is vertical from the same point and while at the surface it shows a dip about as indicated 35°, the steeper correlations show steeper dips so that this must be near a fault. The south bluff shows exposures beginning at the railroad about 3150 feet from the Minnesota conglomerate, perhaps 1700 feet from and 250 feet below the Butler or the top of that ridge. It must be close to the horizon of d 22.

46. Amygdaloid (40)
Ophite

47. Amygdaloid conglomerate (95)
Ophite 4 mm. 165 feet

48. Amygdaloid
Ophite (155)?

49. Amygdaloid conglomerate with much sandy material (10)?
Strike N. 77° E. Total 250-300 paces, 450 feet (300)
This is a section like Mass beds 62-64, or the beds from Adventure 24 on. There are no outcrops farther south. It is covered by the great dissected clay plain at about 418 feet developed in Mass holes, 1, 2, 3 and 4. Here 200 feet and more of heavy clay overburden may be often expected.

§ 28. VICTORIA MINE. (Pl. XV and Figs. 53 and 60.)[1]

The Victoria mine has been drilling and I have prepared a cross-section which is given in Figure 53 with some additions.

The cores were looked over by Mr. R. S. Schultz, Jr., the engineer, and Mr. Meuche. A fine set of samples of the cross-cut, the cross-cut itself as well as the neighborhood in general were also examined so that there are some modifications of the section as printed in their annual report.

The upper part of the section, the Nonesuch shale, found on Section 11, T. 50 N., R. 40 W., Copper Harbor conglomerate beneath found through Secs. 14 and 15, and the felsite ridge with beds above and below in 13, 14 and 15, faulted in 13, are easily identifiable and are at similar distances apart and make an identifiable top. The Rockland Creek section may be matched by outcrops in Section 19, T. 50 N., R. 39 W. The dips seem to be steeper west of the Ontonagon.

At 1131 in the cross-cut is a pumiceous bed which with the sandstone below and conglomerate above from 991 to 1178 (142) feet can be correlated very probably with Adventure 5, Beds 21 to 23 (168-) feet, as it makes up a peculiar group. If so, the Forest conglomerate becomes that great datum plane, No. 8, the top of the Bohemia Range group. 1,900 feet above it we find no sediment to speak of, which also agrees. The bed immediately above is, however, much thicker than elsewhere, although Lake beds 5 and 6 are not so bad a match. About 1,628 feet northeast of the shaft is a slip which throws the east side 50 feet south.

A detailed section of the cross-cut follows, but later drilling is included in figure 53, from Mr. Schultz's notes. See also notes on the distribution of salt water in the mines.

The Victoria mine 19th level cross-cut section. Compiled from notes and surveys and examination of specimens collected by R. S. Schultz, Jr. E. M. The dip at this level is about 54° to 55°; presumably flattening somewhat to the north, since about 3600′ N. a dip of 50° was obtained. Distances along the cross-cut are accordingly multiplied by .82 to reduce to true thickness. The direction of the cross-cut at right angles to the lode is N. 22° 50′ W.

About 1760-1800 feet N. W. of (1400) feet above the shaft is a conglomerate. Cut in No. 3 Hole as shown in Fig. 53.

1. Ophite 3-4 mm. 480 to 570+30? (100)

   The cross-cut goes into the trap of this from 480 to 570 feet from hanging wall of the lode, 650 from the shaft. It seems to be getting slightly finer (2 mm. mottles) and has occasional chlorite amygdules at the end, the coarsest part being at 550 to 540 (about 3 mm. mottles). One may infer that something more than 30 feet (25 feet) would be needed to reach

[1]In envelope.

the top of the flow and the overlying amygdaloid. The rate of increase A is 1 mm. in 16 ft. The augite grain at

570, 560, 550, 540, 530, 520, 510, 500, 490, 480 ft. respectively seems to be
2, 2, 3, 2–4, 2, 1.5–2, 2, 1-2, 1, 0 mm.

The plagioclase laths seem uniformly small in 570, and at 490 they appear about 4 mm. long but somewhat thinner near the margins. At 510 the magnetite granules were about 2 mm. and the altered brown olivine, iddingsite, which shows well in 490 is about the same. Greenish chlorite fills the interstices and replaces the olivine. The specimen at 510 ft. shows a seam with pink and green laumontite and chlorite coating, that at 500 a face with a shining, transparent, glassy coat, hardness 5. There is also calcite and laumontite. Another face is more thickly coated with chlorite.

2. Ophite 8-12 mm. 480 to 183 (240)

The grain at:

480, 470, 460, 450, 440, 430, 420, 410, 400, 390, 380, 370
augite 0, 3(?), 2–3, 2–3, 3–4, 4-6, 4–5, 8, 7–8, 7–9
plagioclase 1.0, 0.8, 0.6, 1.0, 1.0, 1.0, 1.0,
olivine 0.4, 1.0, 0.6

360, 350, 340, 330, 320, 310, 300, 290, 280, 270, 260, 250 is
for the augite 8, 4–6, 4–7, 10–12, 6, 7, 7-10, 6, 4-6, 4, 3–4, 4–5
plagioclase 1.0, 1
olivine 1.0, 1, 1

240, 230, 220, 210, 200, 190
augite 3–5, 3–4, 3, 2, 1–2, 1–2?
plagioclase 1, 1.0
olivine 0.6

The augite is not very regular in grain and seems, e. g., at 330 to have a certain tabular habit and parallel arrangement. The chances are that it was not very uniformly heated and somewhat supersaturated for some reason. The rate of increase A appears to be about 1 mm. in (13) feet. The plagioclase and olivine are coarser than in the belt above, about uniform in size, 1 mm. or so.

It is on the whole massive and fresh, though of course the olivine is altered to reddish iddingsite (?); there are the usual joint faces and seams covered with dark green chlorite at 300, and 290, which also fills interstices and turns the feldspar light greenish; also laumontite in flesh colored fibres on seams and joints at 280, 270, 230, 220. In 440 epidote is notable; in 430 epidote, prehnite, chlorite and calcites in a 8 mm. seam, and bright scales of hematite.

3. Feldspathic melaphyre 183-136 (39+)

This melaphyre has a more pronounced amygdaloid and is probably a smaller flow though some part seems to have been removed by the big slip at its base.

The sample at 183 is very fine grained, with fibrous chlorite full of small pores, and quartz, epidote and prehnite, and probably is just the base of the overlying flow. That at 180 is a red amygdaloid with epidote and quartz amygdules, and feldspar laths of various sizes up to 1 mm. That at 170 is similar with some prehnite in the amygdules and less conspicuous feldspar.

That at 160 has fewer large, white, but more small chloritic amygdules.

That at 150 has but small pores.

The specimen at 140 is fine grained, with considerable feldspar (0.8 mm. long) and greenish decomposition spots.

4. Clay slip, at 136.

This slip is filled with a red unctuous fluccan clay, wet and easily taken out in the upper levels, dry lower down. It is met in cross-cuts from the 4th, 5th, 6th, 18th and 19th levels always at practically the same distance from the vein and may be a typical "slide" or strike fault.

5. Melaphyre 136-100? (25)

This is quite probably not a separate flow, but only a gush of the underlying.

Specimen 130 is reddish amygdaloid with abundant epidote and white prehnite (?).

Specimen 120 is somewhat epidotic with prehnite, the feldspar rather conspicuous on a reddish ground (6-8 mm.).

110 is specked with prehnite changing to chlorite.

6. 3 mm. copper bearing ophite. 100 or less north from hanging to 20 south from hanging (98)

It is in the foot of this ophite that the shattered zone called the Victoria lode occurs. It is noteworthy that minute quantities of copper seem to occur frequently in the trap, not the amygdaloids nor the lode proper. The lode relative to the Evergreen or I. R. lodes is said to be low in silver, high in arsenic. It is a distinct ophite.

The augite grain is at:

40,	30,	20,	10,	0 feet N.,	5 ft. S. respectively
1?,	2–3,	2,	1–2,	1-?	1-?

This gives a rate of increase *from the bottom* of A=1 to 15ft.

But the amygdaloid top is extra heavy. There is possibly a 20-foot separate gush.

At 90 there is a brecciated amygdaloid, red fragments with epidote or brownish and calcite cement.

At 80 the amygdules are relatively few, and the rock is gray with feldspar.

At 70 the amygdaloid with amygdules of epidote and quartz and of calcite is marked.

At 60 it is a trap with apparently amorphous chlorite blotches with very possibly considerable prehnite, and with spangles of *copper*.

At 50 there is also pink prehnite with *copper*.

At 30 the altered olivine (0.4 mm.) the feldspar (0.6 to 0.8 mm.) and the whitish mottlings are common.

At 20 it is also prehnitic with *copper*.

At 10 while the gray trap looks fresh there is a seam of laumontite.

The hanging wall is fine grained ophite with 5 mm. chloritic blotches. It is said to be a fairly well-defined line throughout the mine and marked by shallow saucer-like depressions which remind one of those formed by the "cannon ball" or "onion" disintegrations of diabases. Even when the foot runs along fairly uniformly the hanging wall will occasionally run up into fairly sharp points making the width of the lode vary from 50 to 14 feet.

Five (5) feet S. of the hanging wall at the 19th cross-cut is still clearly a fine grained ophite; the joints coated with laumontite, a thorough trap, in this respect like the Baltic lode in many places.

The foot wall at 20 feet is an amygdaloid but shows no copper.

7. Amygdaloidal melaphyre. Ophite. (?) with trace of copper. 20 S.-88 (?) (56)

The mottling is hardly visible. At 20, 30, 40, 50, and 60 it is a reddish amygdaloid. The amygdules are in the 20-foot specimen of epidote and quartz; at 30 they are more sparse, with chlorite and prehnite also; at 40 more chloritic with some red specks, which are more abundant at 50, where they have red borders with epidote or quartz centers; at 60 there is some prehnite; at 70 it is almost massive; at 78 it is 1 mm. ophite, fine grained, reddish with prehnite and specks of epidote and quartz; at 80 there are amygdules of epidote, quartz, and pink prehnite with a trace of *copper*.

8. Amygdaloidal melaphyre 88-118 30 (25)

This is probably connected with one of the flows above or below. The specimen at 88 is a fine grained amygdaloid of pink prehnite *(copper)* and red bordered amygdules of epidote and quartz. The specimen at 98 is grayer, but shows epidote and prehnite, while that at 108 is greenish gray and shows epidote and quartz. This may belong with the flow below but the grain of the latter does not point that way.

9. Ophite feldspathic, 5-7 mm. 118-528 (343)

It is peculiarly red and massive. An exceptional thing about this, if it be all one flow, as seems most likely, is the fine grain of the augite for the size of the flow, as may be seen by these figures:

distance	208,	218,	228,	278,	298,	318,	328,	338,	348,	358,	368,
diam. of mottles	1,	2,	2,	1,	2–3,	3,	3–5,	5–7,	6,	5–6,	4–6,
	388,	398,	408.								
	2–3,	2,	2.								

The rate of increase and decrease from 268 to 428 is about 1 mm. in 11 ft., quite rapid but at neither place does there appear to be a well-marked contact. This agrees well enough in grain with the ophite under the Bluffs on the Tremont location in the N. part of Section 35, but does *not* look so much like that on the creek. Plate XV.

At 118 the specimen shows amygdules with epidote and quartz, and prehnite and pink border.

At 128 the amygdaloid is red and with small amygdules.

At 138 the amygdaloid is gray, with partially red bordered amygdules, containing epidote, calcite, a trace of copper, etc.

At 148 the specimen contains occasional epidote and pink prehnite specks. It is possible that between this and 158 comes a flow contact, but I think this 158, which contains small amygdules of epidote and prehnite and calcite tablets, is but a bomb. At 168, 178 and 188 the specimens are distinctly a fine grained trap with chloritic flecks.

At 198 it looks a little coarser.

At 208 it is red, fine grained, perhaps a 1 mm. ophite.

The feldspar laths are on the whole usually small; at 218, 0.2mm; 228, minute; and at 248, 258, 328, 508, 518 ft. 0.6 mm. The grain is then only in general half as coarse as flow 2 above the lode.

Chlorite blotches at 248, chlorite and prehnite pores at 268.

Altered olivine may be 0.2 mm.

10. Conglomerate (8) mainly sandstone 528-668 (115)

The specimens are:

At 528 a dark brown sandrock, with granules of felsite mainly and a

poikilitic calcite seam, in contact with the trap which is brown for 3 mm., then greenish for 12 mm., then reddish.

At 538 the cement is yellow, epidotic, the pebbles of red felsite and quartz porphyry.

At 548 the cement is calcite, and the grains of felsite and darker stuff less than 2 mm. across.

At 558 is an amygdaloid with calcite and chlorite slips.

This may be from an intruded block, considered by L. L. H. a separate layer.

At 568, a brown sandstone with calcite cement.

At 578, rounded red pebbles, grains of felsite and prehnite, and a cement of sand and calcite.

At 588 and 598 grains 2 to 4 mm. and smaller, largely basic.

At 608 sandstone with bands coarser and finer, the coarser with calcitic cement, the finer dark brownish red.

At 618, there is a pebble of distinctly porphyritic feldspar porphyry.

At 628, 638, 648 a dark brown sandstone, respectively, less than 1 mm., 1-5 mm. and very fine grained.

At 658 the transition at the base is to an amygdaloidal conglomerate with calcite and laumontite amygdules and fine reddish brown cement.

On the whole the bed seems to be more sandstone than conglomerate, and on the whole finer toward the base. This last is also true of the bed from 998 to 1038. At the top is salt water,—Chapter VII, § 5.

This is the beginning of (530) feet in which there is a large proportion of sediment, 528-668, 998-1048, 1128-1188, and no very heavy trap which should therefore be a marked topographic feature. This is true. The Forest Conglomerate outcrops on the flanks of the hill on the road to the Norwich just S. W. of the Victoria mine location, and there is a fairly continuous valley, with a double ridge S. of it to the Lookout, a triangulation station of the mine survey.

The bed above also seems somewhat characteristic, being rather feldspathic.

11. Feldspathic melaphyre 668-788 (98)

In this bed the feldspar and olivine were probably relatively abundant.

The specimen at 668 is a decomposed amygdaloid with chlorite, epidote and calcite, the feldspar is 1 mm. long on a blue-gray ground.

Those at 678-688 a gray trap with 1 mm. feldspar, and at 688, 1-2 mm. augite.

Those at 698, 708 and 718, similar but look coarser, quite reddish, more so than flows 6-8.

Then at 728 one can see the red specks of secondary hematite after olivine.

In that at 738 the feldspar is 1-6 mm; there are white seams and red blotches of clay enclosures or altered olivine up to 8 mm. across.

In that at 748 the red specks are 2 mm., the general effect is 1 mm. granular; laumontite seams appear.

That at 758 has finer bands of reddish specks.

That at 768 has greenish feldspar up to 3 mm. tending to a glomeroporphyritic nature.

That at 778 has 1 mm. feldspars with specks of chlorite quartz and epidote.

12. Feldspathic melaphyre 788-828+ part cut out? (33+)

The specimen at 788 is amygdaloid, with epidote, quartz crystals, and chlorite, prehnite and traces of *copper*.

That at 798 also shows calcite, epidote, *pink prehnite*, and quartz.

That at 808 shows distinctly 1.6 mm. feldspar, 1 to 2 mm. augite and a green chloritic ground.

About 818 there is a slip, a branch of that at 890 feet (?), the one that cuts the shaft at the 14th level. ?

The specimen is a fine grained, massive, reddish trap with a greenish white joint seam and others parallel.

See notes on slip at 890.

13. Ophite 828-918+ part cut out (74+10?)

The alteration of this bed seems to be affected by the very considerable seam at 890 feet.

The specimen at 828 feet is a red amygdaloid, with greenish prehnite, small amygdules (2 to 3 to <10 mm.) not brecciated.

That at 838 shows very light small mottles ½ x 1 to 1/5 mm., on a gray ground, apparently decomposed augite.

The grain of the augite at:

838, 848, 858, 868, 878, 888, 898, 908 ft. seems to be respectively
.25, 1–2, 2, 2–3, 2–3, 2–3, 1–2 mm.

The rate of increase at A is about 1 mm. in 11 ft., and there is perhaps 10 ft. cut out.

14. Clay slip at 890, is filled with a regular red fluccan clay; dip 45° to 46° to S. Strikes S. 80° W. Passes through the plat of the shaft at the 14th level and strikes the 14th level next, there being a cross-cut of 70 to the level, about 200 W. of the same, dropping the hanging wall down about 10 ft. and temporarily impoverishing the lode.

15. Feldspathic melaphyre 918-997 (73)

The specimen at 918 is a fine grained amygdaloid with epidote, chlorite, calcite (and prehnite?)

That at 928 is blotched and decomposed, greenish gray, with epidote, and abundant red feldspar and augite.

That at 938 is similar, coarser, feldspathic. (2 mm.? augite).

That at 948 is similar, with greenish seams.

That at 958 has 2 mm. feldspar, is full of yellow epidote with chlorite and quartz in small specks (microdruses).

That at 968 shows a speck of *copper*, in the dark chloritic blotches. The feldspar is greenish.

That at 978 and 988 has similar chlorite blotches. The feldspar is greenish.

16. Conglomerate and sandstone 997-1048 (41)

The contact at 997 shows trap on one side, epidotic cement, calcite felsite pebbles and minute veins of calcite crossing them.

The specimen at 998 has an epidotic cement, inch pebbles of not porphyritic felsite dominant, sand of quartz and felsite. There was some *copper* in the hanging.

Those at 1008 and 1018 show a dark sandstone with a few dark pebbles, of quartz and felsite grains <1 mm. round; light green joint seams.

Those at 1028 and 1038 show a change from a quartzose sandstone with calcite to a red argillite or shale. It is like the mud in the amygdaloid conglomerates, and it is not uncommon in this region for conglomerates to have such a base.

17. Amygdaloidal melaphyre 1048-1131 (68)

The specimen at 1048 shows a red amygdaloid with calcite and prehnite amygdules.

That at 1058 is decomposed, with pink and green blotches, and pink spots (laumontite).

That at 1068 is fine grained with specks of quartz, chlorite and laumontite.

That at 1078 is greenish white, with epidote and white specks.

That at 1089 is a typical amygdaloid, with white and greenish amygdules on a maroon ground, disseminated epidote, calcite, prehnite, and probably a trace of copper.

That at 1098 is full of small (1-3 mm.) white amygdules.

That at 1108 is banded with bands of small white amygdules.

That at 1110 is very amygdaloidal, with prehnite and calcite amygdules and much epidote in the gray ground.

That at 1118 is a maroon amygdaloid with light greenish spots.

That at 1128 is a perfect mass of small amygdaloidal pores, (some larger) approaching a pumice, while that at 1131 was a perfect pumice, banded and altered and full of white amygdules, with pink borders. There is a very dark base and a streak apparently of ash and sediment. This may belong with the bed below. Evidently this flow was laid down in the sediment 15 and 17 when the same were wet and the base was heavily steam laden. Something like it is found in the Torch Lake section south of Calumet.

18. Sandstone. 1134-1178 (33)

The specimens at 1134, 1138, 1148, 1168, 1178, are all a dark brown sandstone, with a fine grained felsitic sand. That at 1138 is very heavy and dark.

19. Ophite 1188-1308 (98)

The ophitic character is not plain especially at top. The specimen at 1178 shows the contact of a dark slate blue amygdaloid with white amygdules, while that at 1188 shows smaller white and chlorite amygdules.

The augite grain at:

1198,	1228,	1248,	1258,	1268,	1278,	1288,	1298 ft.	appears to be perhaps
2,	2?,	3–5,	3,	3–5,	2–3,	2,	1–2,	1 mm.

The rate of increase A is perhaps 1 mm.:10 ft.

The feldspar is only 0.4-0.6 mm.

The specimen at 1198 shows the yellow-gray epidotic alteration.

That at 1208 is brecciated with calcite and epidote.

That at 1238 is laumontitic specked and seamed.

That at 1248 has a chloritic joint and is laumontitic.

The trap is generally reddish.

20. Ophite 1308-1438 (106)

The specimen at 1308 is an amygdaloid of epidote and calcite on a dark maroon ground.

That at 1318 is decomposed, slightly amygdaloidal with yellow ophitic ? mottles.

That at 1328 is similar (Cf. 1198) with occasional large amygdules with prehnite, calcite and copper.

The augite grain at:

1318, 1328, 1338, 1348, 1358, 1368, 1378, 1388, 1398, 1408, 1418 ft. appears to be

0.5-1, 1.5, 2, 2–3, 4–5, 4, 7 faint, 5–8, 3, 2, 1–2 mm.
The base is abnormal and the grain shows some irregularities. It is very apparently abnormally coarse toward the base. This may for some reason have been a little extra cool at the beginning of consolidation, or more likely its cooling retarded. The grain from the top down would be about 1 mm. in 10 ft. while from the base ?, which was probably hot when it rolled over it, would be 1 mm. in only 5 feet! There is no distinct amygdaloid beneath, and very likely 19 and 20 would be found to blend elsewhere.

21. Ophite underflow of 19? 1438-1569 (106)

The specimen at 1438 is a decomposed epidote seam with quartz and large (40 mm.) poikilitic patches of calcite (luster mottled).

That at 1448 is the same with curious red flecks on a yellow-green ground.

1458 is a fine grained reddish trap with minute chlorite amygdules, and at

1478 there are chlorite lined pores.

The augite grain at:

1468, 1478, 1498, 1508, 1518, 1528, 1538, 1548 ft. seem to be
2, 2, 2, 3–4, 4, 2–3, 3, 2 mm.

The rate of increase A at the bottom is about 1 mm. in 19 ft. It is notable that just as the bottom of 2 has grain increasing extra fast so that of 20 increases extra slow. This may be explained by a change of heat (or unequal initial heating) from the top of 20 to the bottom of 19.

22. Ophite 1569-1650 (68)

The specimen at 1569 is a typical maroon amygdaloid with epidote bordered quartz and calcite amygdules.

That at 1508 is more massive but has still a hackly fracture and a trace of copper, while that at

1588 has quartz and epidote amygdules on a gray base, and in that at

1590 they are in parallel lines; with epidote pores and a trace of *copper;* even that at 1598 is slightly amygdaloidal, porous and much epidotized. The trap is red and the augite grain at

1608, 1618, 1622 ft. appears to be
2–3, 2, 3 mm. respectively.

The work of Plate XV was done by A. H. Meuche in 1908, assisted by his brothers, Karl and Leon. Mr. R. E. Hore and I were in the area a few days. Mr. P. S. Smith and W. V. Savicki also did some work in 1900.

The horizon of the Forest conglomerate, No. 8, can be carried along easily to Section 34, T. 50 N., R. 40 W. Here there is a gap across the range and a wide swampy valley not over 500 ft. above Lake Superior. But two conglomerates can be found on the other side, the uppermost of which is pretty likely to be the Forest as indicated by Meuche. A fault throwing the east side to he south (like that on Section 13) is suggested and as well a turn of the strike more to the south from southwesterly. This brings us past the Old United States location to Section 4, T. 49 N., R. 40 W., whence it is but two miles to the old Norwich, the Copper Crown Just off the map (Pl. XV) in Section 20 a conglomerate dipping 32° is exposed in a stream about 400 paces north, 700 west of the southeast corner and the position of the felsite and the Ashbed group, can be located also.

An old map of the Canal lands (File 15-28) gives beside the Victoria section of

Plate XV, and the West Minnesota section, a section in Sections 3 and 33 with the following lodes, reckoning south from the west quarter-post of Section 33.

Amygdaloid	at	150 paces
Conglomerate	at	300-400 paces
Amygdaloid	at	600 paces
Road	at	950 paces
Lodes	at	1300, 1450, 1500, 1800 and 1850 paces

One of the two last is meant for the Forest conglomerate without doubt.

Also another at 2075 paces.

The same map gives a section from the Hamilton to the Norwich along the west line of Sections 1 and 12, T. 49 N., R. 41 W., as follows: beds at 0, 150, 250 (apparently the conglomerate of the section just mentioned) 1230, 1430, 1570, 1760, 1880, 2350, 2400, 2460, 2600, 2860,

§ 29. THE COPPER CROWN (NORWICH) MINE. (Pl. VIII.)

Recently some work was done about six miles east of the Victoria on Sec. 11, T. 49 N., R. 41 W., especially in connection with old-time Norwich and Devon conglomerates, and the intervening territory was carefully worked up under the supervision of A. H. Meuche with results shown in Plate XV.

A prospectus issued in 1905 shows five belts of amygdaloid with dip 46°-56°. The company owned 1,000 acres, had two shafts, 75 to 100 feet deep and near the east shaft an adit. The bedded lodes were faulted by a lot of small 10 foot throws, the east side thrown north.

§ 30. PORCUPINE MOUNTAIN. (See Pl. IX, Report for 1908, and Fig. 54.[1])

Dr. F. E. Wright is making a careful study of the Porcupines and a preliminary map will be found in the report for 1908. The section from the base of the Freda sandstone to the Chippewa felsite is given with not much disturbance on the north side of the range. There is no olivine diabase in the Freda sandstone.

The copper deposit worked at the White Pine lies on the northeast side of a fault that strikes northwest. (See Pl. I, Report for 1908.) Near the fault the Nonesuch shales and grits are bent down toward it in approaching it from the north, and are then thrown down several hundred feet. The black shales themselves contain notable quantities of copper, but the most up to 5% is found in the sandstones beneath which are white or grey. The values run down as the red sandstone below is reached (exactly as noted by Weed in New Jersey).

Also and most interesting the values are practically gone on the lower dropped side of the fault, (see Fig. 54).

[1]Plate IX is in envelope.

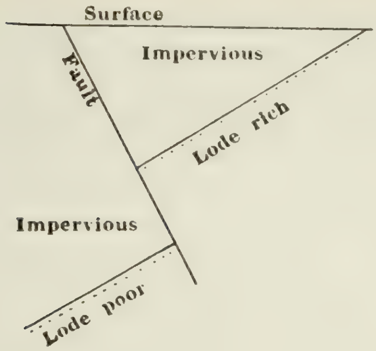

Fig. 54.—Faulting of the Nonesuch Lode at one point on the White Pine.

This might, of course, be well explained by supposing ascending solutions following the fault and then veering off to follow the contact between the pervious sandstones and impervious shales If so, however, one would rather expect a mineralization down the fault line which has not yet been found. This explanation also takes no account of the fact that this particular formation is very widely mineralized,—near Lone Rock, Black River, almost everywhere that I have had a good look at it. We may also assume that the fault line acted simply as a clayey impervious shield to check circulation of any kind along the contact of slate and sandstone. The conditions are illustrated by the records of a number of holes put down by the Calumet & Hecla people.

Beneath this to the Lake Shore trap is clearly the Outer Copper Harbor conglomerate, of which over 200 feet is exposed. A knob of conglomerate is well exposed on Section 36 where the trail to Lafayette Landing turns northwest and a faulted ridge extends to the southwest. It is very coarse, and contains a lot of porphyrite pebbles, with labradorite, oligoclase and acid feldspar. It contains a few of amygdaloid, and occasional pebbles of breccia.

At a 27° dip there would be about (2800) feet
Quite likely as Irving says there is over (3000) feet or as
at Black River (6000) feet
The Lake Shore traps are about (400) feet
fine grained traps with coarse quartzose amygdaloid.

The lowest bed appears to be a 50-foot bed of feldspathic ophite with 1 mm. augite grain and 0.4 mm. feldspar laths. These seem to be three flows along the cliff. No melaphyre porphyrites or intermediate conglomerates show, nor are there any coarse ophites.

But they are mainly amygdaloidal ophites with grain less than 2 mm., and large coarse amygdules, round and white, with more laumontite than epidote. In all respects they resemble Division 4 of the Black River section[1] and there is clearly nothing like them at Rockland where the whole section between Nonesuch and felsite has greatly shrunk. This is the first of many indications that at the Porcupines was a volcanic focus. Beneath we come to the Great Copper Harbor conglomerate which occupies only part (just how much is uncertain) of the interval between the felsite and the Lake Shore Traps. It is certainly included in the interval between a point 1400 paces north 1600 paces west in Section 33 and the east quarterpost of Section 28, T. 51 N., R. 42 W., with flat dips, but we must wait for Wright's detailed work before bettering Irving's estimate of (1800) feet, which is probably a maximum, since on the Black River, 5 with 6a and 6b, which may also be included if the eruptive group 6a is not exposed, only amounts to 1850 feet.

Next follows the Ashbed series, exposed in Sec. 33, T. 51 N., R. 42 W., including one coarse ophite but characteristically feldspar porphyrites and porphyries and based on a heavy felsitic conglomerate which seems to be derived from the underlying felsite which forms the backbone of the Porcupines. This is bounded on the south by a great fault, along which are a mass of smaller faults. On Sections 3 and 4, T. 50, R. 44, the cut in the felsite boundary (Pl. VIII) is not due to a fold but to exclude an intrusive gabbro. Felsite intrusives were also discovered by Wright in Section 4. The very interesting relations here must wait for their full description until his work is ready for publication.[2]

It seems very probable that, as Irving thought, this main mass of Porcupine Mountain felsite is the same as the Chippewa felsite and that it is brought up by the fault shown in the map of the annual report for 1908,[3] repeating the conditions of the great Keweenaw fault on a small scale. (See also Irving's sections[4].)

The normal section should be found in T. 49 N., R. 42 and 43 W. but T. 49 N., R. 42 W. around Bergland has an extensive development of felsite and quartz porphyries, so that it required detailed study. Not only is there a great ridge of porphyry north of the Cascade River, as Rominger pointed out, occupying most of Sections 9, 10, 11, 12, 15, 16 and 17 and extending down into 19, 20 and 21, but as

[1]Report for 1906, p. 430.
[2]See also Wadsworth's work for Longyear and Smith and Savicki's work. Ss. 19518-19703. Note books 157-159.
[3]The elevation of Little Carp Lake there given as 900 feet is that above Lake Superior. It should be 1602 above sea level.
[4]Monograph 5 and Figs. 1 and 2, Report for 1905.

Wadsworth notes there are similar rocks intrusive in a great belt of ophites (up to 8 mm. mottles) in Sections 26, 34 and 32, and 500 paces south of the south corner between 31 and 32. These intrusives are other signs of nearness to a volcanic focus. So too is the appearance of traps of the Keweenawan lapping up on the iron ranges south of Lake Gogebic.[1] They are many of them porphyrites rather than ophites, have flat dips, and might represent some of the Ashbed series, though if so there are marked differences, and the Black River section would suggest rather that they belong in the Bohemian Range Group.

Beyond the Porcupine Mountains comes the Presque Isle River described by Irving[2] and similar in section to that at Black River except that the north and south ranges of Keweenawan have not come together.

§ 31. BLACK RIVER. (Fig. 55[1]) (Pl. 33 of Report for 1906.)

A detailed section of the Black River was given by Gordon in the 1906 report.[2] For convenience we may summarize it here with the nomenclature herein used, adding the section of sandstone on the Montreal Upper Keweenawan.

1. *Freda* sandstone — (5000+ ?) on Montreal River
2. *Nonesuch* shales — (500)
3. *Outer* conglomerate. Outer *Copper Harbor conglomerate* — (5000)
4. Lake Shore Trap. Five flows (35), (35), (115), (85) and (130) feet thick respectively — (400)
5. Conglomerate just like the Middle or Great Copper Harbor conglomerate — (350)
6. Mixed eruptives and sedimentaries — (5500)

   about 38 belts, about 3000 feet unexposed, with at least 7 sandstones and conglomerates 20 to 30 feet thick generally, down to the base of the Chippewa felsite but the lower eight beds are more felsitic, only Beds 20 to 24 being distinctly ophitic. We may divide this into

   6a. Six beds of melaphyre possibly belonging to the Lake Shore traps but probably to the Eagle River Series. Thicknesses, (60) + (90) + (180) + (90) + (180) + ? — (600)

   6b. Covered 1200=(Gordon's 16 and 17)= — (900)

   ends in conglomerate, perhaps largely conglomerate and sand-

[1]The scattered traps of what used to be called the South Range, rising from the Eastern sandstone begin at Silver Mt. and are exposed in Sec. 16 near by on the Ontonagon. They are shown on a map prepared by Denton for the Chicago exposition, and in a map in the report for 1901.

[2]Monograph V, U. S. G. S., pp. 208-220. See also Pls. XXI to XXIII and Pl. I of Report for 1908.

[1]In envelope.

[2]P. 421 and Pl. XXXIII and illustrations.

stone. This is as far as the Great conglomerate could possibly come.

6c. Melaphyres Nos. 8 (40) and 19 (40), ophites 20 (75) and 21 (70); faulting; melaphyre (80) sandstone (30) dip 42°, ophite, conglomerate (20), melaphyre (25) melaphyre (25), melaphyre (25) melaphyre (60) melaphyre (20) melaphyre No. 31 (40) melaphyre (20) sandstone (25) dip 44°, 4 melaphyres (30), (70), (140)? feet.

The Eagle River series may end here with from (835) feet thickness up.

6d. No. 38 gap unexposed for 900 feet, in which somewhere is probably the top of the Ashbed series; the beds are distinctly more felsitic.

Ashbed group

6e. No. 39. Conchoidal fracture porphyrite (90)

40. And 41 quartzless porphyries (90) + (90)

42. Sandstone 30)

43. Melaphyre (45) +

44. Unexposed (170)?

45. Sandstone (20)

46. Melaphyre (70)

47. Conglomerate (100+)

Unexposed, largely felsite perhaps (1300)

7. 48. Chippewa felsite (500)

Below this within 200 feet are 5 mm. ophites so I do not hesitate to place this felsite here at the base of the Ashbed series, which in that case would be between 3500 and (2500)

8. 50. A sandstone. Under the Chippewa felsite; would then be the Mesnard.

51 and 52 are ophites (80)

53. An acid sandstone; would be the Allouez No. 15 conglomerate (10)

55. A felsite sandstone and conglomerate

56 to 58 are ophites

59. Is unexposed

60 to 61 are ophites

63, 64 and 65 are like Ashbed rocks (900)

This is the end of nearly continuous sections, but down to 72 no sandstones are noted.

73. Is about 100 feet thick of sandstone like the Wolverine. about 17000 feet horizontally below the felsite at (1300)

78. About 1200 below is a feldspar porphyry of unknown thickness. 800 feet below this is unexposed.

80. Is the coarsest ophite seen with mottles up to an inch across.

81. Is another

Below these ophites is 8500 feet unexposed in which it is more than possible that great strike faults like those that bound the south side of the Porcupine Mountains and Keweenaw Point pass so that it is

doubtful how much we need to add for thickness, if anything.

9. The porphyrites are much like (and may be considered provisionally equivalent to) the *Bohemian Range* group. There is a strong tendency toward coarsely porphyritic 30 mm. labradorite porphyrites. Felsite occurs and there are intrusive diabases as well as a gabbro sill. Ophites are rather the exception. Amygdaloid conglomerates occur. Down to the gabbro are 41 beds, and but little of the column unexposed Nos. 83-124 (4800)

 This group reminds me somewhat of the Ashbed group but is so different that I hardly think it can be a faulted repetition of the same. The presence of intrusives also suggests a lower position.

10. A 200 ft. gabbro sill is intrusive, coarsely granitic, not much like the Mt. Bohemia gabbro but more like the Bad River gabbro to the west.

11. Melaphyres and labradorite porphyrites occur below with but little sediment, numerous flows with well-marked contacts and pipe amygdules (125 to 187) 62 of them about (4500)

12. The basal sandstone has but 300 feet exposed, and not always that as the Neo-Huronian is unconformably overlapped by the Keweenawan. (300)

§ 32. MONTREAL RIVER.

The last section in Michigan in this section is that of the Montreal River and neighborhood. It will be found described by Irving[1] and some corrections by myself.[2] The noticeable thing is that we are back to a type of section like that at Rockland. The Lake Shore traps seem to be gone. The Outer and Great conglomerate are merged in one Copper Harbor conglomerate. We have:

Freda sandstone	(5000) +
Nonesuch shales and sandstone	(350) +
Copper Harbor conglomerate	(1200)
Twenty-six small beds of the Eagle River Group	(1212)

Nos. 2, 4, 8, 14, 22 and 26 are sediments, only 14 conglomeritic, the rest red sandstone and shale, showing that we are leaving their source. This is the end of the section on the river, but felsites, ophites and gabbros may be found farther south and west exposed here and there, the felsites near the D. S. S. and A. track, and as Irving remarks gabbros become more abundant, and the red rocks (gabbro aplites) associated with them.

The indication is clear that the Porcupine Mountains were a volcano, a center both of erosion and outpour late in Keweenawan history. But it was not the only center. Another was at Mt. Bohemia. The last outburst of Lake Shore Traps at the two centers seems to have been nearly simultaneous, though probably

[1]Monograph V, pp. 226-229.
[2]Annual Report for 1908.

enough the beds are not actually continuous, and will not be found between Portage Lake and the Ontonagon River.

On the road north from Ironwood about one-half mile (2,800 feet) north of Section 2, T. 47 N., R. 47 W., is a diabase dike striking north 25° east, dipping 25° only to south (so that though 80 steps broad, it is but 30 or 40 feet thick) and is cutting labradorite porphyrites. We are safe then in assuming that at least this far and probably to the D. S. S. and A. track just above the north line of the section belong to the Bohemian Range group.

These labradorite porphyrites which mark the lowest group of the Bessemer Section, which I take perhaps to be the Bohemian Range group I have traced into Wisconsin where a little exploring was done about 300 paces north, 500 paces west in Section 16, T. 46 N., R. 2 E. The plagioclase phenocrysts are up to 15 mm. long, and the agate amygdules and pipe amygdules at base are all like the beds between Bessemer and North Bessemer.[1]

§33. SOUTH TRAP RANGE.

There is one occurrence of Keweenawan Rocks that deserves farther study. I refer to that which lies south of the Great Keweenaw fault. Gordon has given a pretty close study of it north of Bessemer. It branches from the Main Trap Range near Abitosse. It shows at the Castile mine, Section 10-13, T. 47 R. 46, where it seems to roll up onto an eroded surface of the iron formation with flatter dips at the upper levels, and the labradorite porphyrites are close to the iron formation north of Sunday Lake, showing a heavy pre-Keweenaw erosion of the Animikie.

East of Lake Gogebic in Sections 5, 4 and 9, 10, 11, 12 and 13, T. 46 N., R. 41 W., the traps appear and seem to have nearly flat dips, judging by the steepness of the south scarp and the course of the outcrops curving around the east and west ends. The jointing is nearly vertical (columnar and horizontal). Bands of amygdules are probably parallel to the bedding, and very rarely interbedded sandstones are found. I judge that the dips were often less than 10° to the north. On Section 11 a contact with sandstone showed 14° dip. (See Ss. 14119-14124.) On Section 13, there seems to be a feeder neck of diabase. A. E. Seaman studied this region in 1891. (Note book 85.) Some of these beds are labradorite porphyrites and they look like the lowest group. Pipe amygdules at base and agates (datolite) are not really important but suggestive. They are probably quite unconformably overlapped by the Jacobsville or

[1]Farther description of the Keweenawan rocks and of detailed work to the west will be found in a report by F. T. Thwaites to the Wisconsin Geological Survey.

Eastern sandstone, for not only do patches occur along the edge of these Sections (1 to 18, T. 46 R. 39 to Section 29, T. 48, R. 37) but they appear through it.

The most famous case of this kind is the so-called Silver Mountain Sec. 1, T. 49 N., R. 36 W., and Secs. 6 and 7, T. 49 N., R. 35 W., W.) described by Foster and Whitney[1] but this only dips 10° to 20°. The dike observed by Foster and Whitney at Silver Mountain suggests that it belongs in the lower third of the Keweenawan. Seaman also noticed chalcocite, chalcopyrite and bornite. Another exposure[2] not far off is on the Sturgeon River in Section 16, T. 49 N., R. 35 W., where the river cuts a deep valley with amphitheaters a mile across and 250 feet deep. Both these are typical Keweenawan amygdaloid and trap flows. None of these are known close to the Great Keweenaw fault, however. Whether the disturbances like those of Limestone Mountain, Fig. 48, and Traverse Island, and one-half mile from the south line of T. 50 (F. & W., p. 69) have any connection with similar, not uncovered, phenomena remains to be seen.

§ 34. ISLE ROYALE. (Pl. I[3] and Fig. 56.[4])

This was the first and most completely studied section, especially microscopically. Since Volume VI is out of print I hardly think an apology is needed for presenting this one section on the north shore of the basin. It will be noticed that the section may be closely matched with the Central, Ashbed and part of the Eagle River groups, that the Lake Shore traps cannot be identified, and that the Central group is relatively thin, while the Ashbed group and the Greenstone are well developed, the latter being much thicker to the north where around the head of Rock Harbor are suggestions of a buried felsite laccolite above the Greenstone, i. e., in the position of the Chippewa and Porcupine Mountain felsite.

The drill hole record has to be supplemented by field observations which were roughly as follows:

Red sandstone of Point Houghton.

This has also been called Siskowit Point and an analysis of the sandstone which was quarried on this point is given in the table of analyses (XIX No. 4, p. 118.) The rock was quarried and used in Duluth and that is the reason the Minnesota Survey made a test. Owing to the fault shown in the geological map of Isle Royale the thickness of this formation is uncertain. A very considerable dip is shown, however, at Point Hough-

[1]Part I, 1850, p. 68. See also Seaman's note book 85 and Ss. 14000-14047.
[2]For some of the other outcrops see the map of Michigan in the report for 1901.
[3]Pl. I is a combination of Pl. I of Vol. VI and Pl. I of the Biological Report for 1908. Fig. 56 is a reproduction of Pl. II of Vol. VI.
[4]Plate I and Fig. 56 are in envelope.

ton where the dips are decided, about 20½°. The dips of the minor islands of Siskowit Bay are considerably less. I refer to Wright Island and similar islands but it is not at all impossible that these represent an unconformable overlap of the Lake Superior or Freda or Saint Croix sandstone upon the Lower Keweenawan. At the same time the dip of the Keweenawan, as shown in the conglomerate of the north side of Siskowit Bay, is not very great, being about 12°. I assume for these deep maroon red sandstones a thickness of (2000) ft.

Between the Point Houghton sandstone which would correspond to the Freda sandstone in appearance and stratigraphic relation, though possibly not in age and drill hole XI, comes conglomerate. The cement is often very calcareous; the color is prevailingly bright red. Pebbles of various types of Keweenawan lavas such as melaphyres and porphyrites are quite common and pebbles of agate such as the agates that grow in the Minong trap and other of the Keweenawan lava flows are not rare. The thickness I took to be (600) ft.

(See Isle Royale report, page 56).

Eagle River Group.

Marvine's (c)

Isle Royale Section abstracted from Volume VI, with additional notes.

The reasons for the dip and correlations assumed will be found in Vol. VI. The *vertical* width of the beds, i. e., along the drill holes, is given in feet in the right hand column without parentheses (N. B. not the *horizontal* width which Marvine gives) and under it in parentheses is given the true thickness as found by subtracting a correction equal to (vertical width) x (1-cos dip). In the main body of the text appears first, numbers that denote the limits, in feet, of the several beds below the tops of the respective drill holes. Then follow, in parentheses, high numbers which refer to the thin-sections of rocks from the respective beds; collection of Michigan Geological Survey.

To this are added the petrographic notes and notes on the grain. The dimensions of the grains are given in terms of an eye piece micrometer, the divisions of which represented a length of about 1/30 mm. By adding the observations on three grains and pointing off two places one obtains directly an average value in mm. In giving the extinction angles of the feldspar, those of the two halves of an albite twin are separated by a dash thus 0°-15°, while the conjunction or w joins them to the extinction of a Karlsbad twin which is compounded with them.

DRILL HOLE No. XI.[1]

0-17; (Ss. 15544-5). Ophite; fine grained, massive, with red and white fine grained veins; lustre-mottlings visible. This is near Marvine's bed No. 7, Eagle River section.

Sp. 15544. Hole 11 at 143 feet from surface. Augite patches, sharp feldspar imbedded; labradorite (24°-23° and 30°; 16°-2° and 46°; 39°-30° and 16° albite and Karlsbad extinction). Olivine all green with iron oxide borders secondary; also chloritic areas; little or no feldspar in them; hematite plates whose primary character is doubtful; biotite secondary in with the chlorite; the chlorite appears

[1] Top of No. XI, dip assumed 12° 20′; cos dip=0.9763.

to either fill interstices or replace glass. It contains most of the altered olivine, vein serpentine occurs in fine grained mosaic and in fibres parallel and normal to vein. Distance from margin-14.5 feet.

Grain

Olivine 8; 13; 10; 10; 9; 4: av. .26
Iron oxide 5x0.5; 12x1: av. .28x.02
Feldspar (15 to 20)x5
Augite 40x70; 60; 55; 70; 73

Sp. 15545. Hole 11 at 143 and 144 feet from surface. Much plagioclase; augite less conspicuous; altered olivine altered to red oxide, much viridite after olivine and glass? in fibrous coating covering the carbonates and feldspars where they project into probably original cavities; augite shows traces of idiomorphism. Distance from margin 1 ±

Grain

Olivine 7, 7, 8, 7, 5
Iron oxide, of various size, hard to distinguish primary and secondary dust.
Feldspar 7x2, 10x2, 9x2 av. .26x.06
Augite 14x5m, 15x8 av. .48x.21
Thickness (2600+17)

17-90; (Ss. 15546-63). CONGLOMERATE; red with calcareou cement and a great variety of pebbles; the acid quartz porphyry predominates, but felsites, porphyrites and melaphyres are also present. Marvine's bed No. 8 Eagle River.

Sp. 15546. Hole 11 at 18 feet from bed rock surface; calcareous cement with twinning lines; rounded pebbles:

(1) Quartz in the form of porphyry phenocrysts, poikilitic quartz additions, probably secondary, in the conglomerate.

(2) Feldspar porphyry pebbles, patchy poikilitic ground mass, orthoclase phenocrysts.

(3) Porphyry with mosaic ground, very reddish with oxide dots.

(4) Porphyrite; angular iron oxides, feldspar laths with extinction angles near 0° otherwise seems very like 15545.

(5) Porphyritic; angular iron oxides, minute feldspar laths but in polarized light patchy poikilitic texture secondary. Cf. Bascom, J. G. I. (1893) p. 814.

Sp. 15547. Hole 11 at 20 feet from bed rock surface. Calcareous cement, grains like 15546 but smaller; in the porphyrite grains the feldspars are changed to some zeolite, twin striations rare; low extinction angles.

Sp. 15548. Hole 11 at 24 feet from surface. Slightly glomeroporphyritic (Extinctions 6°-4°, 6°-6°, 2°-3°, 17°-10°) oligoclase; ground mass of minute feldspar trichites; iron oxide arranged in concentric rings around certain spots; apatite well marked; other phenocrysts decomposed. Distance from margin 7.

Grain

Iron oxide 6, 5, 4, 7
Feldspar 82x10, 35x13, 43x7, av. 1.10x.25
Feldspar trichites 2x0.2, 3x0.2

Sp. 15549. Hole 11 at 28 feet from bed rock surface. Pebbles of hornblende porphyrite like 15548 of augite, porphyrite; ground mass of quartz porphyry and poikilitic patchy ground masses; calcareous cement; conglomerate (with altered rhyolite, trachyte, andesite and basalt pebbles). Distance from margin 11.

Sp. 15550. Hole 11 at 32.5 feet from bed rock surface. Phenocrysts of corroded feldspar with numerous narrow striations 12°-4°; 16°-4°; not sharp margins; ground mass patchy, poikilitic, mass of smaller feldspar laths mottled with iron

oxide; little quartz veins; more decomposed than 15548. Distance from margin 15.

Sp. 15551. Hole 11 at 37 feet from bed rock surface. Porphyry and porphyrite pebbles. Distance from margin 19.

Sp. 15552. Hole 11 at 43 feet from bed rock surface. Pebble much like 15548; Manebach twin phenocrysts but ground apparently microlitic; really secondarily poikilitic; phenocrysts corroded; one grain like altered olivine; conglomerate. Distance from margin 25.

Grain

Olivine 27? 20?

Iron oxide 5, 4 and dust $<.1$

Feldspar 45x15, 80x35, 80x50, av. 2.05x1.00 mm.

Sp. 15553. Hole 11 at 46 feet from bed rock surface. Rounded fragments quartz porphyry etc., poikilitic and microlitic ground mass; calcareous cement. Distance from margin 28 feet from bottom, 43 from top.

Sp. 15554. Hole 11 at 61 feet from bed rock surface. Quartz porphyry with microfelsitic and poikilitic ground mass and other fragments. Distance from margin 28.

Sp. 15555. Hole 11 at 63 feet from bed rock surface. Oligoclase porphyry, poikilitic ground, other phenocrysts decomposed. Distance from margin 26.

Sp. 15556. Hole 11 at 68 feet from bed rock surface.

Sp. 15557. Hole 11 at 71 feet from bed rock surface. Finer grained calcareous cement; numerous grains dark with iron oxides. Distance from margin 21 ft. and 17 ft. respectively.

Sp. 15558. Hole 11 at 76 feet from bed rock surface. Chalcedonic fragments also. Distance from margin 14 ft.

Sp. 15559. Hole 11 at 78 feet from bed rock surface. Decomposed melaphyre pebble. Distance from margin 12 ft.

Sp. 15560. Hole 11 at 80 feet from bed rock surface. Poikilitic (patchy) felsite; no phenocrysts, fluidal texture. Distance from margin 10 ft.

Sp. 15561. Hole 11 at 83 feet from bed rock. Fragments porphyry and porphyrite with much secondary poikilism. Distance from margin 7.

Sp. 15562. Hole 11 at 88 feet from bed rock surface.

Sp. 15563. Hole 11 at 89 feet from bed rock surface. Some epidote; various pebbles; one shows spherulitic porphyry. Distance from margin 2 ft. and 1 ft. respectively.

Thickness of cross-section (2600+86)

The large number of these sections of this conglomerate were made to identify the pebbles with underlying beds. Almost all the material was derivable from Keweenawan lavas.

90-96; (Ss. 15565-6). MELAPHYRE, thin and amygdaloidal, (6) with chloritic amygdules; slightly ophitic; small flow perhaps a mere gush of the underlying.

Sp. 15565. Hole 11 at 94 feet from bed rock surface. Slightly ophitic, pores full of delessite fibres (+ex. o. biref. .008+), feldspar extinction angles 15° and 26° 35°, 15°-31°, 12°-15°, 29°-41°, 35°-25° and 17°, 20°-22° and 33°-37° labradorite; olivine changed to serpentine, coated with red oxide; carbonates. Distance from margin 42.

Grain

Olivine 8, 4, 5, 5, 6

Iron oxide much red secondary 3-4

Feldspar 17x2, 20x2, 24x4, 18x2, av. .65x.16
Augite 26x10, 20x18, 40x20, 25x8, av. .89x.47

Sp. 15566. Hole 11 at 96 feet from bed rock surface. Marginal plagioclase much decomposed, in small forked and skeletal trichites and larger crystals (all sizes) on a glassy decomposed ground, stained red brown and opaque with rust; calcite amygdules; no augite visible; primary iron oxide not recognized; iron oxide of ground tends to gather in little knots, around which is a lighter halo; primary vein amygdules with calcite; altered olivine? and rare small amygdaloid pores. Distance from margin 0.

Grain
Olivine 5x3, 7x6, 9x6 (? double)
Feldspar from 3x.02 up to (porphyritic) 30x6, 12x1, 15x1, 25x3, 17x4, 42x16, av. .66x.10.

(2600+92)

96-103; (Ss. 15567-8). MELAPHYRE, amygdaloidal. While (7)
not coarse enough, that is not thick enough flows to show the characteristic texture to the naked eye, these two small beds appear to belong to the ophites, with calcite, quartz and zeolite amygdules.

Sp. 15567. Hole 11 at 97 feet from bed rock surface. Very calcareous amygdaloid and feldspathic; small extinction angles 2° to 6°; possibly a few augite granules but cf. epidote; altered olivine? augite porphyrite. Distance from margin 1.

Grain
Olivine 2; 3; 4x5? 7x5; 8x6
Iron oxide 5?
Feldspar 22x1; 18x3; 20x8, av. .60x.12
Augite not clearly recognizable.

Sp. 15568. Hole 11 at 98 feet from bed rock surface. Very amygdaloidal, calcite, quartz and some zeolite; feldspar (0° with 14°-12°) and two types of ground mass one near 15566, the other to 15567; augite decomposed (?); very trichitic.

Grain
Feldspar 10, 9, 8, 10, 10, 13x1
Augite 45?

(2600+99)

103-124; (Ss. 15569-72). MELAPHYRE, ophite. The upper 5 21
feet are amygdaloidal, and make, with the above two small (20) (2600+119)
flows, one amygdaloid belt. A very thin SEDIMENT with a calcareous cement underlies this bed. 0

Sp. 15569. Hole 11 at 107 feet from bed rock surface. Like 15570 but finer grained. Altered olivine is heavily coated with iron oxide. Distance from margin 4 ft.

Grain
Olivine 9x8; 7x7; 14x10, av. .30x.25
Feldspar 25x2
Augite 30x30 30x30; 30x14, av. .90x.74

Sp. 15570. Hole 11 at 114 feet from bed rock surface. Like 15571. Distance from margin 11.

Grain
Olivine 14x10; 9x5; 7x5; crowded between the patches of augite. Av. .30x.20
Feldspar 20x2; 20x2, av. .66x.06
Augite 80x45; 50x35; 45x40, av. 1.75x1.20

Sp. 15571. Hole 11 at 120 feet from bed rock surface. Poikilitic augite; olivine changed to talc; abradorite extinctions (23°-45° and 35°-22°; 24°-17° and 42°). Distance from margin 17 feet to top and 4 to bottom.

Grain

Olivine 10; 10; 10

Feldspar 22x4

Augite 65x40; 100x40; 50x35, av. 1.15x1.15

Sp. 15572. Hole 11 at 124 feet from bed rock surface. Glass like 15566, feldspars less microlitic, more basic; rests on fine grained ash or clay bed; poikilitic calcite cement; contact of melaphyre and sandstone; probably a very short break between this flow and the next above. Margin.

Gra n

Olivine } not clear
Augite } not clear
Iron oxide } not clear

Feldspar 23x4; down to minute microlites 2x2; 7x5; 5x2

124-137; (Ss. 15573-5). MELAPHYRE, amygdaloidal. Marvine's bed No. 16. 13

This bed is so glassy that it shows it was not only thin but in a cold place as indicated by the thick conglomerate over which it flowed, whereas the bed above may have almost immediately succeeded and hence cooled more from top than bottom.

Sp. 15573. Hole 11 at 127 feet from bed rock surface. Much calcite, much decomposed olivine, trichitic feldspar. Distance from margin 3 feet to top, 6 feet to bottom.

Grain

Olivine 11; 8; 7

Sp. 15574. Hole 11 at 133 feet from bed rock surface. Porphyritic and trichitic; olivine decomposed; various sized; distance from margin 9 feet to top, 4 to bottom.

Grain

Olivine 7; 4

Feldspar 27x2 and trichites 4x0.1 etc.

Sp. 15575. Hole 11 at 136 feet from bed rock surface. Very amygdaloidal; trichitic; decomposed; calcareous; slightly coarser than 15574. Distance from margin 3 ft.?

Grain

Olivine 4; 6; 6; 5

Feldspar 17x2

Thickness in cross section

(2600+132)

137-146; (Ss. 15576-9). CONGLOMERATE; r d, with the usual porphyry and felsite pebbles. Perhaps equivalent to Marvine's bed No. 17. 9

Sp. 15576. Hole 11 at 137 feet from bed rock surface. Rather coarse cement; decomposed orthoclase. Poikilitic quartz ground section is probab y of a pebble?

Sp. 15577. Hole 11 at 138 ft. from surface. Fragments (1) trichitic porphyrites like augite porphyrites, (2) glass with iron oxide hairs, (3) poikilitic ground masses of quartz, (4) chloritic porphyrite, (5) quartz porphyry with calcareous cement. Conglomerate. Distance from margin 1 ft.

Sp. 15578. Hole 11 at 140 feet from surface. Spherulitic quartz porphyry with Manebach oligoclase phenocrysts, also some augite; porphyrite fragments. Distance to top 3 ft., to bottom 6 ft.

Sp. 15579. Hole 11 at 143 feet from bed rock surface. Oligoclase porphyrite, poikilitic ground mass.

Sp. 15580. Hole 11 at 146 feet from surface. Various sized down to trichitic feldspar (extinction 0°-10° in Baveno twin cut nearly perpendcular to symmetry plane) ferruginous base. Distance from margin 0.

Grain

Feldspar 18x1, 12x2.

Sp. 15581. Hole 11 at 147 feet from bed rock surface. Epidote vein; oligoclase phenocrysts, flow structure apparently; bits of porphyry ground mass, also poikilitic with secondary quartz, oriented after trichitic feldspar, as described by Bascom sedimentary granules of porphyry ground mass. Distance from margin 1.

Grain

Feldspar phenocrysts 25x10, 30x10, 30x20, 6, 4, 7 trichites. (2600+141)

146-154; (Ss. 15582-3). PORPHYRITE (?), amygdaloidal. I 8
think it is not impossible that this is merely a boulder in the conglomerate, as we have the conglomerate again interrupted by something similar (S. 15585).

Sp. 15582. Hole 11 at 149 feet from bed rock surface. Calcareous decomposed; glassy, diabasic; much feldspar. Olivine not apparent, nor augite. Distance from margin above, 3/5 below.

Grain

Iron oxide 5x5; 4x4; 3x2; 11x1; 12x1; 9x1. av. 24x.05.

Feldspar 42x2; 25x3; 40x9, av. 1.07x.14

Sp 15583. Hole 11 at 153 feet from bed rock surface. Amygdaloid; fine grained diabasic porphyrite; augite porphyrite pebble? Distance from margin 1.

Grain

Iron oxide 4x8, 5x4, 7x2 or dust av. .16x.14

Feldspar 7x1, 7x1, 8x1, av. .22x.03 (2600+149)

154-159; (S. 15584). CONGLOMERATE, as above 5

Sp. 15584. Hole 11 at 155 feet from bed rock surface. Contains pebbles of oligoclase porphyry and semi-spherulitic porphyry like 15578 and 15581, with calcareous cement. (2600+153)

159-161; (S. 15585). PORPHYRITE, like S. 15583 2

Sp. 15585. Hole 11 at 160 feet from bed rock margin. Just like 15583. All low angled. Distance from margin 161?

Grain (2600+155)

Feldspar 10x1; 13x1; 15x3, av. .38x.05.

161-198; (Ss. 15586-99). CONGLOMERATE; continued, growing 37
finer and passing into red sandstone in the last 7 feet. (36)
It seems to me quite possible that we have in these last 59 feet only one bed of conglomerate which will correspond about to Marvine's bed No. 17, but his sandstones, Nos. 17, 19 and 21, are separated by single flows, and more or less conglomeritic, and our conglomerate may represent the whole of them.

Sp. 15586. Hole 11 at 164 feet from bed rock margin. Oligoclase porphyrite, (apatite?). No phenocrysts, partly microlitic and hypidomorphic ground mass; brown and white flecks.

Sp. 15587. Hole 11 at 165 feet from bed rock surface. Pebbles; spherulitic quartz porphyry, like 15578; poikilitic oligoclase porphyry like 15579; diabasic andesite porphyrites like 15582; calcareous cement.

Sp. 15588. Hole 11 at 168 feet from bed rock surface. Conglomerate like 15587; porphyry with apatite.

Sp. 15589. Hole 11 at 170 feet from bed rock surface. Quartz porphyry; poikilitic.

Grain

Quartz 17x12; 23x24; 27x33, av. .67x.69

Feldspar aggregates 80x80; 60x70, av. 2.3x2.5

Sp. 15590. Hole 11 at 180 feet from bed rock surface. Forms like olivine in porphyry, pebbles of porphyry as above, chalcedony.

Sp. 15591. Hole 11 at 181 feet from bed rock surface. Fine grained quartz porphyry; glass; spherulites; chalcedony; biotite.

Sp. 15592. Hole 11 at 184 feet from surface. One big pebble; porphyrite; rest is quartz porphyry, calcareous cement.

Sp. 15593. Hole 11 at 188 feet from surface. Diabase porphyry; oligoclase porphyrite; ground mass delessite.

Sp. 15594. Hole 11 at 191 feet from bed rock surface. Usual fragments, in coarse calcareous cement. 191 is bottom of conglomerate, beneath is sandstone.

Sp. 15595. Hole 11 at 192 feet from surface. Calcite appears to be a secondary infiltration but see also clastic type of calcite 8x8.

Sp. 15596. Hole 11 at 192.5 feet from bed rock surface. Calcite with small rounded and green grains of altered olivine?

Sp. 15597. Hole 11 at 194 feet from bed rock surface. Down to fine grained shale.

Sp. 15598. Hole 11 at 195.5 feet from bed rock surface. Fine grained calcite and chalcedony with clastic fragments larger, about 23 to 30.

Sp. 15599. Hole 11 at 198 feet from bed rock surface. Quartz, feldspar, chalcedony, labradorite porphyrite and green fragments. (2600+191)

198-209; (Ss. 15600-4). MELAPHYRE, amygdaloidal 11

Sp. 15600. Hole 11 at 199 feet from bed rock surface. Amygdules; finer grain around them; much decomposed; diabasic to trichitic texture; olivine ? decomposed to sericitic (talcose) or isotropic matter. Distance from margin 1.

Grain

Olivine 13x5, 13x5, 12x8, av. .38x.18

Feldspar near amygdules 7x0.5, 5x0.5, 3x0.2, 10, 14x3, 15x2.

Sp. 15601. Hole 11 at 204 feet from bed rock surface. Coarser; much labradorite, ext. 21°-23° and 37°; some augite left; numerous olivine pseudomorphs. Distance from margin 5.

Grain

Olivine 12x10, 14x11, 10x7, av. .36x.28

Feldspar 12x3, 22x3, 23x5, av. .57x.11

Augite 13x12, 23x21, 22x9, av. .58x.42

Sp. 15602. Hole 11 at 206 feet from surface. Growing finer grained trichitic with quartz and calcite amygdules; in contact with fine grained sediment; arrangement perpendicular or parallel to contact and growing coarser away from it; trichites often arranged to the contact; feldspar extinction angles trifling at contact. This flow is more compact at 206 feet with an enclosure or vein of sandstone in trap. The sandstone is bedded with the laminæ curving relative to the wall.

Grain

Olivine not plain

Feldspar 5x0.5, 2x0.2, 6x0.2, av. .13x.09

Augite not plain.

Sp. 15603. Hole 11 at 207 feet from bed rock surface. Like 15601, labradorite ex. 26°-21°? Coarsest part of belt? Distance from margin 2.

Grain

Olivine 20x8; 17x17; 13x12, av. .50x.37

Feldspar 12x3; 20x2; 16x2, av. .48x.07

Augite 30x22; 20x20; 27x23, av. .77x.65 (2600+202)

UNCERTAIN.

Sp. 15605. Hole 11 at 212 feet from bed rock surface. Amygdaloidal; decomposed glass and sandstone contact; no trichites; only phenocrysts; like 15605; very irregular contact— Feldspar phenocrysts like 15604 groups. (2600+204)

212-222; (Ss. 15606-9). MELAPHYRE, ophite; amygdaloid and feldspathic. 10

Sp. 15606. Hole 11 at 215 feet from bed rock surface. Porphyritic, amygdaloidal, with fine grained zone of forked trichite; feldspar about andesite? Rock highly feldspathic varying rapidly in character in belts (as the samples indicate) of more and less amygdaloid. Distance from margin small.

Grain

Olivine 10x10; 20x12; 20x15, av. .50x.37

Feldspar trichites 3x0.1; 4x0.2; 2½x0.1, av. .09x.004. Porphyritic 15x4; 14x4; 22x4, av. .51x.12.

Sp. 15607. Hole 11 at 216 feet from bed rock surface. Probably the same bed with decomposed olivine; glomeroporphyritic feldspar?

Grain

Olivine 14x12; 13x8; 11x9, av. .38x.29

Feldspar phenocrysts 16x3; 20x2½; 22x4, av. .58x.08.

Sp. 15608. Hole 11 at 217 feet from bed rock surface. Amygdaloid with much red altered olivine; feldspar extinctions 9°½-7° with 14°-14°½ then latter with lower birefringence 28°-15° with 5°; red altered olivine.

Grain.

Olivine 10x9; 8x6; 12x9, av. .30x.24

Feldspar varied, the larger 21x2, 12x1.5, 25x4, av. .58x.07.

Sp. 15609. Hole 11 at 221 feet from bed rock surface. Fresher though altered olivine; labradorite extinctions 30° and 26°-16°; anorthite 21°-30° and 45°-45°, 29°-32° and 35°.

Grain

Olivine 9x4; 13x8; 16x13, av. .38x.25

Feldspar 25x7; 12x3; 22x4, av. .59x.14

Augite 18x5; 20x15; 65x17 (extra large), av. 1.03x.37 (2600+214)

222-266; (Ss. 15610-19). MELAPHYRE, ophite; about 17 feet of 44
amygdaloid at top and 9 feet at the bottom. Perhaps they are (43)
two minor flows. We have distinct SEDIMENTARY matter in the parting at bottom.

Sp. 15610. Hole 11 at 223 feet from bed rock surface. Amygdaloidal; trichitic; decomposed olivine; small amygdules.

Grain

Olivine 10; 9; 5

Feldspar 8x1; 16x2; 13x3, av. .37x.06.

Sp. 15611. Hole 11 at 226 feet from bed rock surface. Olivine, augite, labradorite, ex 29° and 35°-37°.

Grain

Olivine 14x8; 13x8; 16x8, av. .43x.24

Feldspar 20x2; 25x3; 40x7, av. .85x.12

Augite 37x33; 60x30; 40x30, av. 1.37x.93.

Sp. 15612. Hole 11 at 228 feet from bed rock surface. Fine grained amygdaloid; trichitic; thoroughly decomposed, with calcite.

Grain

Olivine 15x12; 13x10; 13x12, av. .41x.34

Feldspar 30x8; 20x4; 21x3, av. .71x.15.

Sp. 15613. Hole 11 at 232 feet from bed rock surface. Decomposed olivine; labradorite; ex 24°-21° and 31°, fresher augite.

Grain

Olivine 8x6; 12x5; 12x6, av. .32x.17

Feldspar 11x2; 20x3; 40x3, av. .71x.08

Augite 30x20; 23x10; 24x22, av. .77x.52.

Sp. 15614. Hole 11 at 235 feet from bed rock surface. Amygdaloid; decomposed trichitic around the amygdaloid. If a real gap here the overlying flow must have followed soon as the coarse zone lies so near the top. Distance from margin 24 ft. from below, at upper margin?

Grain

Olivine 16x15; 19x16; 16x13, av. .51x.44

Feldspar 22x3; 26x4; 18x3, av. .66x.10.

Sp. 15615. Hole 11 at 239 feet from bed rock surface. Decomposed olivine; augite; groups of (ex 11°-24° and 34°-39°) labradorite; iron oxide largely secondary? around decomposed olivine; apatite needles in interstices. Distance from margin 4 from above, 20 from below.

Grain

Olivine 4; 21; 13x8

Iron oxide 22x15; 20x15; 7x17, av. .59x.47

Feldspar 28x4; 24x4; 40x3, av. .92x.11

Augite 130x50; 80x70; 80x60; 70x53, av. 3.00x1.11.

Sp. 15616. Hole 11 at 251 feet from bed rock surface. Like 15615 (labradorite or anorthite ex 30°-24° and 43°-38°) iron oxides associated with olivine. Coarsest along here. Distance from margin above 16, 8 ft. below.

Grain

Olivine 18x13; 14x10; 10x8, av. .42x.31

Feldspar 25x2; 30x4; 60x4, av. 1.15x.10

Augite 70x45; 70x40; 70x30, av. 2.10x1.15.

Sp. 15617. Hole 11 at 257 feet from bed rock surface. Like 15616; anorthite with extinction angles 41°-44°-; 37°-43°; 23°-22°. Distance from margin 2.

Grain

Olivine 20x13; 15x12; 23x12, av. .58x.37

Feldspar 20x4; 22x4; 20x3, av. .62x.11

Augite 35x25; 30x18; 30x20, av. 95x.63.

Sp. 15618. Hole 11 at 259 feet from bed rock surface. Arborescent augitic amygdaloid with calcareous and chalcedonic trichitic zone around amygdules, labradorite (ex 44°-37°), augite not as solid as above; more fibrous and twisted. Melaphyre.

Grain

Olivine 12; 11; 8; 7

Iron oxide 3; 4; associated with olivine

Feldspar 30x4; 30x3; 30x4, av. .90x.11

Augite 30x20; 35x20, loose texture, av. 1.08x.66.

Sp. 15619. Hole 11 at 264 feet from bed rock surface. Like 15618; amygdaloid clusters; corroded olivine.

Grain

Olivine 9x4; 25x15; 14x10

Feldspar 24x4; 25x7; 20x4

Augite 30x8; 12x10 loose texture. (2600+258)

266-275; (Ss. 15620-1). MELAPHYRE, amygdaloidal; from 272 (9) to 275 the amygdules are not so prominent.

Sp. 15620. Hole 11 at 266 feet from bed rock surface. Fine grained; marginal porphyritic, mixed in with sediments.

Grain

Olivine 11x9

Feldspar porphyritic 58x68 and ground indefinitely small to 8x2.

Sp. 15621. Hole 11 at 268 feet from bed rock surface. Augite; labradorite; altered reddened olivine; delessite. Distance from margin 2 above, 7 below.

Grain

Olivine 8x8; 9x4, av. .28x.20

Feldspar 20x5; 20x4; 30x4, av. .70x.13

Augite 33x10; 30x12; 28x5, av. .91x.27.

(2600+267)

275-283. (Ss. 15622-3). MELAPHYRE, amygdaloidal; 2 feet (8) amygdaloidal at top, the rest compact. It is really a fine grained ophite, as most of these beds are, but they are too thin for the structure to develop so as to be visible to the unaided eye.

Sp. 15622. Hole 11 at 26 feet from bed rock surface. Very fine grained nearly amygdaloidal, trichitic, augite tends to be sheaf like. Decomposed olivine; much interstitial; quartz or feldspar. Distance from margin 1 foot.

Grain

Olivine 8x9; 13x13; 9x8, av. .30x.30

Feldspar 28x7; 50x7; 13x3, av. .91x.17

Augite 35x10; 30x6; 22x5, av. .87x.21.

Sp. 15623. Hole 11 at 280 feet from bed rock surface. Serpentine after olivine; poikilitic augite; labradorite (ex 36°-36° and 27°-16°). Augite not typical, pink, broken into patches too much. Distance from margin 5 ft. above, 3 below.

Grain

Olivine 10x8; 16x10; 12x8, av. .38x.26

Feldspar 20x3; 30x5; 20x4, av. .70x.12

Augite 10x4; 30x20; 30x15, av. .70x.39.

(2600+275)

283-302.5; (Ss. 15624-6). MELAPHYRE, amygdaloidal; the upper 9 feet amygdaloid, with *copper* (at 289 feet), prehnite and quartz. (18)

Sp. 15624. Hole 11 at 284 feet from bed rock surface. Fine grained decomposed porphyritic amygdaloid like 15622 "283-293 Amygdaloid" *copper*, prehnite, quartz. Distance from margin 1 ft.

Grain

Olivine 12x8

Feldspar 33x8; 25x2; 25x5, av. .83x.15.

Sp. 15625. Hole 11 at 295 feet from bed rock surface. Augite, labradorite, decomposed olivine; less amygdaloid than 15624 augite small.

Distance from margin 12

Grain

Olivine 15x11; 16x10; 14x12, av. .45x.33

Feldspar 35x12

Augite 10x8 10x4, av. .33x.20.

Sp. 15626. Hole 11 at 302.5 feet from bed rock surface. Augite in minute granules, labradorite, decomposed olivine; occasional large feldspar.

Grain

Olivine 12x8; 10x9, av. .36x.28

Feldspar 40x10; 30x4; 18x4, av. .88x.18.

(2600+293)

302.5-305; (Ss. 15627-8). SHALE, red, indurated; in vein- 2.5
contact with trap. Dip measured on drill cores, 14°. (2)

Sp. 15627. Hole 11 at 304.5 feet from bed rock surface. Bands of finer grained sediment cemented by coarser 2 to 3/32nds mm., all red; quartz and feldspar with iron oxides.

Sp. 15628. Hole 11 at 305.0 feet from bed rock surface. Light colored; yellowish skeined; sedimentary; apparently indurated.

(2600+296)

305-311; (Ss. 15629-33). CONGLOMERATE, with pebbles of melaphyre (6)
as well as of felsite; toward the bottom fine-grained and epidotic.
Dips measured on the cores 18° and 14°. This is about the same distance above the bed that we correlate with Marvine's Eagle River bed No. 53, as is Marvine's No. 21. The very fine and partly indurated character of Marvine's bed No. 21 accidentally matches our two feet of red shale.

Sp. 15629. Hole 11 at 305.5 feet from bed rock surface. Labradorite, augite prisms,? decomposed olivine, much augite; small grains not marked

Grain

Olivine 15x11; 20x13, av. .75x.40

Feldspar 20x2; 24x6; 22x7, av. .66x.15

Augite 16x10; 12x10; 8x4, av. .36x.24.

Sp. 15630. Hole 11 at 307 feet from bed rock surface. Conglomerate largely felsitic debris, poikilitic orthophyre? also some porphyrite. Distance from lower margin 3 ft.

Sp. 15631. Hole 11 at 307 feet from bed rock surface. Sedimentary, quartz grains from quartz porphyry; serpentine (?) cement.

Sp. 15632. Hole 11 at 308 feet from bed rock surface. (Melaphyre pebble, augite, labradorite decomposed, olivine). Distance from margin 2.

Grain

Augite 3x2; 7x4; 7x3, av. .17x.09.

Sp. 15633. Hole 11 at 310 from bed rock surface. Fragmental, fragments epidotic; calcareous cement.

(2600+303)

311-327.5; (Ss. 15634-8). MELAPHYRE, ophite; amygdaloidal; 16.5
is markedly amygdaloidal for about 4 feet, then mildly spotted—somewhat more so at the bottom. The contact with the conglomerate dips 19°. If the overlying bed is the same as Marvine's No. 21, this may represent bed No. 22, which is mentioned by Irving as a typical representative of his ordinary diabases. In this flow the olivine grains are notably small.

Sp. 15634. Hole 11 at 311 feet from bed rock surface. Very fine grained, trichitic, decomposed; decomposed olivine; iron oxide in lines as it occurs in glass. Distance from margin 0.

Grain

Olivine 14x8; 3x3; 6x3; 5x3, av. .23x.14

Feldspar 3x0.2; 6x0.2; 8x0.5, av. .17x.009.

Sp. 15635. Hole 11 at 317 feet from bed rock surface. Coarser,—tends to poikilism. Distance from margin 6.

Grain

Olivine 6x4; 3x3; 7x7, av. .16x.14

Augite 33; 20; 15

Sp. 15636. Hole 11 at 321 feet from bed rock surface. Augite poikilitic; labradorite; serpentine after olivine associated with iron oxide. Distance from margin 10 above, 6.5 below.

Grain

Olivine 7; 10; 10; 10x18

Feldspar 15x6; 13x2; 13x2, av. .41x.10

Augite 70x60; 45x40; 40x40, av. 1.55x1.40.

Sp. 15637. Hole 11 at 326 feet from bed rock surface. Fine grained, somewhat amygdaloidal. Distance from margin 1.5.

Grain

Olivine 5; 4; 9

Feldspar 20x1; 10x3; 12x2, av. .42x.06.

Sp. 15638. Hole 11 at 327½ feet from bed rock surface. Still finer grained and darker; olivine absent from the finer grained halos around amygdules. Distance from margin 0.

Grain

Olivine 4; 6; 7

Feldspar 13x2; 13x4; 20x3, av. .46x.09.

(2600+319.5)

327.5-344; (Ss. 15639-42). MELAPHYRE, ophite; amygdaloidal for the first 7 feet. (16)

Sp. 15639. Hole 11 at 329 feet from bed rock surface. Distance from margin 1.5.

Sp. 15640. Hole 11 at 333 feet from bed rock surface. Amygdaloid; sedimentary coating peeled off by secondary calcite veins. Distance from margin 5.5.

Grain

Olivine 2-3?

Iron oxide club shaped 10x1

Feldspar 20x2; 24x2, av. .73x.66

Augite 34x30.

Sp. 15641. Hole 11 at 338 feet from bed rock surface. Poikilitic augite, much magnetite associated with it. Distance from margin 10.5 ft. above, 6 below.

Grain

Olivine 12; 12; 8

Feldspar 14x2; 20x2; 15x1.5, av. .49x.05

Augite 85x45; 43x40; 48x42, av. 1.76x1.27.

Sp. 15642. Hole 11 at 343 feet from bed rock surface. Fine grained trichitic, porphyritic; very ferruginous. Distance from margin 1.

Grain

Olivine 5x4, 10x8?, av. .25x.50

Feldspar 8x0.2 and larger and smaller.

(2600+335.5)

344-349; (Ss. 15643-4). MELAPHYRE, amygdaloidal (5)

Sp. 15643. Hole 11 at 348 feet from bed rock surface. Coarser, somewhat poikilitic, augite is larded with labradorite. Distance from margin 4 ft. above, 1 below.

Grain

Olivine 7x4; 15x6, av. .36x.16

Feldspar 15x8 and smaller
Augite 22x10; 10x10; 17x13, av. .49x.33.

(2600+341.5)

349-362; (Ss. 15644-6). MELAPHYRE, ophite; about 7 feet (13) at the top and 1 foot at the bottom are amygdaloidal. Sp. 15644. Hole 11 at 349 feet from bed rock surface. Fine grained; very amygdaloidal; trichitic contact. Distance from margin 0.

Grain
Olivine 3x4?

Sp. 15645. Hole 11 at 356 feet from bed rock surface. Much serpentinized olivine; poikilitic augite; labradorite; much like part of 44. Distance from margin 7.

Grain
Olivine 5; 10; 9
Feldspar 25x2 and smaller
Augite 30x12; 37x18; 23x13, av. .90x.43.

Sp. 15646. Hole 11 at 358 feet from bed rock surface. Like part of 44, poikilitic augite; grouped individuals in patches; larded with labradorite (ex 23°-25° and 33°-35°). Distance from margin 9 ft. above, 4 ft. below.

Grain
Olivine 12; 10
Augite masses 65; 55; 60; 70x53; 40x38; 50x43 (2600+354)

362-370. (Ss. 15647-50). MELAPHYRE, ophite; about 3 feet at 8 the top are amygdaloidal.

Sp. 15647. Hole 11 at 363 feet from bed rock surface. Altered olivine; augite; andesite, fine grained, small irregular amygdules, slightly porphyritic. Distance from margin 1.

Grain
Olivine 5x4; 7; 17x10
Feldspar 34x8 and trichites
Augite 3x4; 7x5; 2x3, av. .12x.12.

Sp. 15648. Hole 11 at 364 ft. from bed rock surface. Labradorite larded in poikilitic augite; altered olivine, much delessite. Distance from margin 2 above, 6 below.

Grain
Olivine 12x10; 8; 13x9
Feldspar 30x3; 30x2, av. 1.00x.08
Augite 90x70; 77x45; 70x50, av. 2.37x1.65.

Sp. 15649. Hole 11 at 368 feet from bed rock surface. Much serpentinized olivine; augite small; labradorite. Distance from margin 2.

Grain
Olivine 6x5; 7x5; 7x7, av. .20x.17
Feldspar 15x2; 11x2; 10x2, av. .36x.06
Augite 40x20; 10x10; 45x40, av. .95x.70.

Sp. 15650. Hole 11 at 370 feet from bed rock surface. Patches of augite, fine grained porphyritic.

Grain
Olivine 9; 6; 5
Feldspar 16x7,—mainly much finer
Augite 20x20, 10x8, 8x8, av. .38x.36 2600+362

Comparing these sections there is no noticeable gathering of iron at the bottom.

370-384 (Ss. 15651-5). Melaphyre, amygdaloidal; possibly two flows. 14 376

Sp. 15651. Hole 11 at 370½ feet from bed rock surface. Very fine grained trichitic, porphyritic; amygdaloid; in the filling the amygdules show horizontal plane; *top* of *flow* red.

Grain

Olivine 7, 5, 4

Feldspar phenocryst 30x27; ground 8x1; 6x0.5; 9x2 and smaller, av. .23x.03.

Sp. 15652. Hole 11 at 373 feet from bed rock surface. Decomposed olivine; augite; feldspar, ex 30°-36° and also low angles; tends to poikilitic texture. Distance from margin 2½ above, 3 below.

Grain

Olivine 5; 5; 4

Feldspar 20x5

Augite 30x30; 20x13; 33x6, av. .83x.49.

Sp. 15653. Hole 11 at 376 feet from bed rock surface. Fine grained glomero-porphyrite with feldspar; no augite? amygdaloid; trichitic feldspar. Distance from margin 0. Apparently margin 15653 and 15654 may have been changed.

Grain

Olivine 15x12; 8x7; 5x2

Feldspar phenocrysts 9x0.5; 47x11; 12x1.5, av. .68x.13.

Sp. 15654. Hole 11 at 381 feet from bed rock surface. Poikilitic augite; decomposed olivine; calcite; labradorite. In my original description of the hand specimens, 15654 is said to be amygdaloid, but it is not so much so as 15653. Distance from margin 5 ft. from above, 3 from below.

Grain

Olivine 6; 4; 7

Augite 23x23; 35x22; 18x13, av. .76x.58.

Sp. 15655. Hole 11 at 382 feet from bed rock surface. Fine grained marginal; slightly porphyritic in feldspar. Distance from margin 2.

Grain

Olivine 2½; 4; 5x4

Feldspar 23x5; 10x2; 4x0.1, av. 37x.07.

(2600+376)

384-389; (Ss. 15656-7). Melaphyre, amygdaloidal. All these amygdaloids show great variety in size of feldspar without any sharp dividing line, that is they are "seriate porphyritic" of Iddings (Igneous Rocks, p. 196).

Sp. 15656. Hole 11 at 385 feet from bed rock surface. Decomposed olivine; augite; ground amygdaloid; trichitic and seriate porphyritic feldspar. Distance from margin 1.

Grain

Olivine 9x7; 6x4; 10x10, av. .25x.21

Feldspar from 45x16; to 9x2; 8x2, av. .62x.20

Augite 9x4; 13x4; 20x8, av. .42x.16.

Sp. 15657. Hole 11 at 387 feet from bed rock surface. Poikilitc augite; serpentinized olivine; labradorite. Distance from margin 3 above, 2 below.

Grain

Olivine 7; 6; 10x4

Feldspar 11x1; 15x2; 12x2, av. .48x.05

Augite 25x17; 30x25; 25x20, av. .80x.62.

(2600+381)

389-396; (Ss. 15658-60). Melaphyre, amygdaloidal. (7)

Sp. 15658. Hole 11 at 389 feet from bed rock surface. Porphyritic feldspar; marked amygdules; trichitic. Small angles feldspar (andesite) around them; (decomposed olivine?). Distance from margin 0.

Grain

Feldspar 90x45; to 0.3.

Sp. 15659. Hole 11 at 390 feet from bed rock surface. Amygdaloid with secondary poikilitic texture; quartz patches, melaphyre. Distance from margin 1.

Grain

Olivine 4x4; 3; 2; 7; 5

Feldspar 15x1, 10x1, 8x1, av. .33x.03.

Sp. 15660. Hole 11 at 394 feet from bed rock surface. Much decomposed olivine; augite more abundant in part of section is from melted enclosure; 7°-7° low angled andesite. Distance from margin 5 above, 2 below.

Grain

Olivine 7x6; 8x5; 8x5; av. .25x.18

Feldspar 10x1; 9x2; 24x12; 14x1

Augite 20x8; 80x70; 37x30, av. 1.37x1.08.

396-457; (Ss. 15661-8). MELAPHYRE, ophite; first 20 feet or more amygdaloidal, then a fine grained black trap, with the lustre-mottling showing somewhat. 61 386? (59)

Sp. 15661. Hole 11 at 396 feet from bed rock surface. Amygdaloid; andesite; altered olivine; augite? Distance from margin 0.

Grain

Olivine 8x3

Feldspar 14x2; 12x3; 2x.1, av. .28x.06.

Sp. 15662. Hole 11 at 403 feet from bed rock surface. Amygdule; poikilitic augite; olivine; feldspar. Distance from margin 7.

Grain

Olivine 7; 5; 6

Feldspar 17x1.2; 12x4.0; 15x2.5, av. .44x7.7

Augite 22x13; 40x30; 120x45, av. 1.82x88.

Sp. 15663. Hole 11 at 411 feet from bed rock surface. Well marked poikilitic (7 mottles in 15 mm.). Distance from margin 14.

Grain

Olivine 12x7; 7; 5

Feldspar 13x1.5; 14x6; 23x2, av. .54x.09

Augite 80x70; 100x55; 84x55, av. 2.64x1.80.

Sp. 15664. Hole 11 at 420 feet from bed rock surface. Decomposed; only a little augite left. Distance from upper margin 23 ft.

Grain

Feldspar 25x2; 25x2; 10x2, av. .60x.06.

Sp. 15665. Hole 11 at 426 feet from bed rock surface. Poikilitic augite; eldspar much decomposed; decomposed olivine. Distance from margin 30 ft. above, 31 below.

Grain

Olivine 9x8; 9; 11x7

Feldspar 60x30?, 14x10, av. 1.23x.66

Augite 70x70; 70x70; 66x50, av. 2.06x1.90.

Sp. 15666. Hole 11 at 439 feet from bed rock surface. Porphyritic Bytounite (ex 45°-42° and 33°, 43° and 10°). Poikilitic augite, decomposed olivine. Distance from margin 18.5.

Grain

Olivine 10; 6; 4

Iron oxide 6x2; 6x1, av. .20x.05

Feldspar 26x6; 36x16; 70x36, av. 1.32x.58

Augite 115x40; 108x80; 104x66, av. 3.27x1.86.

Sp. 15667. Hole 11 at 455 feet from bed rock surface. Labradorite ex 30°-29° with 15°-8° and elongate chloritic pipe amygdule showing an undoubted bottom; much altered olivine. Distance from margin 2.5.

Grain

Olivine 9x5; 3 x3, av. .20x.13

Feldspar 15x1.5; 12x1; 8x2, av. .35x.045.

Sp. 15668. Hole 11 at 457 feet from bed rock surface. Amygdaloid; calcite and chlorite; feldspar very much decomposed, trichitic. Distance from margin 0 5 ft.

Grain

Olivine 7x7; 5x4; 7x4, av. .19x.15

Feldspar 7; 9; 16; phenocrysts 75x24 (2600+445)

457-458; (Ss. 15669-71). SANDSTONE, dark, basic; 1

porphyry fragments not marked. This may represent Marvine's bed No. 26.

Sp. 1566 9. Hole 11 at 457.5 feet from bed rock surface. About a foot of sandstone underlain by andesite and datolitic fragments of porphyrite, epidote, plagioclase, aug:te; porphyry fragments absent or not marked; cement not calcareous. Distance from margin 0.

Sp. 15670. Hole 11 at 457.5 feet from bed rock surface. Basic sandstone.

(2600+445.5)

458-482; (Ss. 15671-6). MELAPHYRE, ophite; first 6 feet an (24) 445.5 amygdaloid with datolite, then a fine grained black trap, finally distinctly mottled. At the base there is a sediment. Compare Marvine's bed No. 27.

Sp. 15671. Hole 11 at 457.5 feet from bed rock surface. Contact of melaphyre with thoroughly altered sediment. Distance from margin 0.

Grain

Olivine 12x7; 14x12; 8x8, av. .34x.27

Feldspar—smaller 2x0.1; 3; larger 43x5; 18x5; 17x4, av. .78x.14.

Sp. 15672. Hole 11 at 458 feet from bed rock surface. Decomposed olivine; and plagioclase. Distance from margin 0.5.

Grain

Olivine 9x8; 13x8; 11x5, av. .33x.21

Feldspar 20x2; 25x5; 25x4, av. .70x.11.

Sp. 15673. Hole 11 at 463 feet from bed rock surface. Poikilitic augite, olivine changed into bowlinglite or material between serpentine and mica. Distance from margin 5.5.

Grain

Olivine 14x13; 12x7; 17x12, av. .43x.32

Feldspar 20x5; 25x4; 18x4, av. .63x.13

Augite 45x45; 65x50; 60x40, av. 1.70x1.35.

Sp. 15674. Hole 11 at 475 feet from bed rock surface. (Bowlingite or iddingsite) mica and serpentine after olivine; poikilitic augite, each mottle made up of parts of slightly diffe ent orientation; chloritic cavities corresponding to acid interstices; labradorite, ex 28°-32° and 39° -; 36°-40° and 30°. Distance from margin 17.5.

Grain

Olivine 15x8; 15x12; 17x16, av. .47x.36

Feldspar 21x12; 18x3; 24x12, av. .63x.27

Augite 60x50; 50x40; 80x60; 90x45, av. 2.33x1.62.

Sp. 15675. Hole 11 at 476 feet from bed rock surface. Fine grained amygdaloid; decomposed feldspar and olivine; augite?

Grain

Olivine 13x9; 17x10; 12x10, av. .42x.29

Feldspar 17x8, and down to trichites.

Sp. 15676. Hole 11 at 482 feet from bed rock surface. Very fine grained marginal amygdaloid; amygdules in part filled with sand, trichitic; large decomposed olivine; plagioclase.

Grain

Olivine 7x7; 13x12; 17x12, av. .37x.31

Feldspar 22x4, down to trichites. (2600+469.5)

482-492; (Ss. 15677-9). MELAPHYRE, ophite; first 5 feet (10) (479.5) amygdaloidal; below that a fine grained trap, the bottom of the bed apparently gone.

Sp. 15677. Hole 11 at 485 feet from bed rock surface. Beginning of poikilitic bed; much altered olivine; labradorite ex 23°-23° and 40°-39°.

Grain

Olivine 13x10; 12x8; 18x12, av. .43x.30

Feldspar 23x2; 10x1; 15x2, av. .48x.05.

Sp. 15678. Hole 11 at 487 feet from bed rock surface. Poikilitic, clasolite vein but not an intrusive contact as the grain is too coarse. It might be erosion contact.

Grain

Augite 22x17; 13x12; 25x23, av. .60x.52.

Sp. 15679. Hole 11 at 491 feet from bed rock surface.

Grain

Olivine 15x14; 12x10; 26x25, av. .53x.49

Feldspar 30x4; 23x5; 17x6, av. .70x.15

Augite 40x40; 55x45; 45x22, av. 1.40x1.07

(2600+479.5)

The coarseness of the grain here is decidedly in favor of a fault beneath.

492-493; (Ss. 15680-1). Seam of red CLAY FLUCCAN, perhaps (1) (480.5) marking a fault. A fault throwing the south side down, and hading to the south "a so-called slide" would make a gap which we could not detect (see p. 35, Fig. 5 of Vol. VI, Part I, Mich. Geol. Sur.), but we may be reasonably sure that there is no fault which would lead to a repetition farther north of the beds we have already described, for these consist of a number of sandstones and conglomerates with thin basic melaphyres of the ophite type, whose texture is sometimes coarse enough to be recognized, and these we do not again encounter. After two more conglomerates, we come to a series of somewhat less augitic flows, with nonfelsitic conglomerates.

Sp. 15680. Hole 11 at 492 feet from bed rock surface. Very fine grained red shale; almost no action on polarized light, i. e., no quartz; regular fluccan.

Sp. 15681. Hole 11 at 493 feet from bed rock surface. Thoroughly decomposed; fine grained, microlitic; with pseudomorph of olivine phenocrysts.

Grain

Olivine 13x12; 17x13; 15x14, av. .45x.39

Feldspar 13x4.

(2600+480.5)

Sp. 15682. Hole 11 at 493 feet from bed rock surface. Microlitic porphyritic; evidently under contact; margin very dark; feldspars arranged with reference to it; magnetite ground.

Grain

Olivine 24x15; 20x16; 18x14, av. .62x.45

Iron oxide 5x0.1; 4x0.1; 2x0.1, av. .11x.003

Feldspar 2 to 3x0.1 and more.

493-499; (Ss. 15683-89). CONGLOMERATE, with porphyry (6) (487.5) felsite, and trap pebbles, and not much calcareous cement; dip about 13°-14°.

499-500. CLAY; another seam, which may indicate a fault. Thus, as the conglomerate may be bounded by possible fault planes above and below, we cannot be certain of its correlation, and it may be a repetition of some higher or lower conglomerate, but relatively to our general correlation it is nearly in the position of Marvine's No. 28.

Sp. 15683. Hole 11 at 494 feet from bed rock surface. Fragments of quartz porphyry, with microlitic and poikilitic ground mass.

Sp. 15684. Hole 11 at 498 feet from bed rock surface. Mainly one pebble of orthophyre, more oligoclase phenocrysts; poikilitic; with altered biotite.

Sp. 15685. Hole 11 at 496½. Orthophyre; porphyrite and spherulitic porphyry pebbles.

Sp. 15686. Hole 11 at 498 feet from bed rock surface. Orthophyre pebbles.

Sp. 15687. Hole 11 at 499 feet from bed rock surface. Pebbles of ophitic melaphyres, poikilitic andesitic porphyrites?, quartz porphyry and calcite cement.

Sp. 15688. Hole 11 at 499 feet from bed rock surface. All carbonates nearly.

Sp. 15689. Hole 11 at 499 feet from bed rock surface. No section—perhaps a slide here?

(2600+487.5)

500-507.5; (Ss. 15690-2). MELAPHYRE, amygdaloidal. 7.5

Sp. 15690. Hole 11 at 499½ feet from bed rock surface. (7) 494.5

Mainly carbonates, here and there shreds showing texture of fine grained trap microlitic erosion contact? or pebble?

Grain

Feldspar 18x2; 10x1.

Sp. 15691. Hole 11 at 504 feet from bed rock surface. Contact of sandstone vein with original margin of trap but coarse; yet there is a continuous black wavy fine line, wrapping projecting feldspar at margin.

Grain

Olivine 7x6; 6x6; 5x4, av. .18x.16

Iron oxide 7x6 4x4, av. .18x.16

Feldspar 27x2; 24x1; 14x2, av. .65x.05

Augite 50x15; 52x13; 18x12, av. 1.20x.40.

Sp. 15692. Hole 11 at 507.5 feet from bed rock surface. Amygdaloid; microlitic; porphyritic evidently marginal; olivine decomposed; quite red.

Grain

Olivine 5x5; 6x5; 7x7, av. .18x.17

Feldspar 18x5; 10x2; 11x3, av. .39x.13

Augite ? not over 4 or 5.

(2600+494.5)

507.5-511; (S. 15693). AMYGDALOID; may belong to the flow 3.5 above or to that below. (3)

Sp. 15693. Hole 11 at 511 feet from bed rock surface (2600+497.5)
10. bed rock surface -113.
11. 511-525; (Ss. 15694-6) MELAPHYRE, ophite; more or less 14
amygdaloidal, especially the first two feet. 2600+ (511)

Here we pass from hole No. XI to hole No. X. Assuming that hole No. XI at 525 feet is equivalent to hole No. X at 113 feet, which will make a difference of 412 feet; adding the excess of altitude of No. X over No. XI (206.7-143=64 feet), makes 476 feet, and dividing by the distance between them, 2,191 feet, we have 0.218 as tan of dip; i. e., the dip is 12° 20′.

The rest of No. XI we correlate as follows:

Hole No. XI at 532 feet, contact, is equivalent to hole No. X at 123 feet, difference, 409 feet. Hole No. XI at 536 feet, contact, is equivalent to hole No. X at 133 feet; difference, 403 feet and the characters of the beds assumed to be equivalent harmonize very well. Full arguments for the correlation are found in the Isle Royale report.

If the dip is steeper than we assume and the two holes do not overlap at all, we have made the column too short.

Sp. 15694. Hole 11 at 512 feet from bed rock surface. Fine grained chloritic; patches of decomposed olivine granules as if derived from breaking up of a large grain; low angled feldspar.

Grain

Olivine 5; 5; 7x7

Feldspar 10x1; 10x2; 14x1, av. .34x.04.

Sp. 15695. Hole 11 at 520 feet from bed rock surface. Largely decomposed; begins to be ophitic.

Grain

Olivine 5; 5; 8; 8; 3; 7x9

Feldspar 12x2; 10x2; 12x1; 14x2; 24x3; 10x2, av. .45x.06

Augite 10x10.

Sp. 15696. Hole 11 at 522 feet from bed rock surface. Labradorite extinction angles 25°-19°; 15°-21° with 35°-21°; 30°-40° and 28°. Distance from margin below 4 ft.

Grain

Olivine 5; 4; 5

Augite 70x50; 50x30; 30x20, av. 1.50x1.00

Sp. 15462. Hole 10 at 109 feet is probably from the same flow as Sp. 15696 perhaps 4 feet from the bottom at 113 ft. It should then correspond in texture pretty closely to Sp. 15696. Being nearer the surface of bed rock, however, it is more altered. The olivine is turned to ferric oxide. The labradorite feldspar is also much attacked, but the extinctions fit so far as they can be made out (28° and 15°-20°, 18°-24° and 36°). There is a heavy impregnation of carbonates. The augite is poikilitic.

Grain

Olivine magnetite pseudomorphs as a unit—6; 7; 8; 10x6

Feldspar (phenocrysts 55x7) 8x2; 20x1.5; 14x2

Augite 35x35; 75x50; 57x47.

(2600+511)
direct computation

Hole 11. 525-532 (Ss. 15697-8) (10) (512)

Hole 10. 113-123; (Ss. 15463-5). MELAPHYRE (2600)+(522)

Sp. 15463. Hole 10 at 113 feet from bed rock surface. Fine grained; amygdaloidal decomposed. Distance from margin 0?

Grain

Olivine 7x5; 6x4; 8x5, av. .21x.14

Feldspar 5x0.5; 10x2; 15x1, av. .30x.03

Augite 12x8; 16x15, av. .46x.38.

Sp. 15697. Hole 11 at 525 from surface. Microlitic; porphyritic, rather low angled feldspar; ex. angles 0°; 6°-7°; 16-13°; 0°; 7°; 0°; calcareous amygdaloid redder. Distance from margin 0.

Grain

Olivine 5; 5; 5

Feldspar 4½x.1 microlites; 7x1.

Sp. 15464. Hole 10 at 118 feet from bed rock surface. Labradorite extinction 35 and 19-22°; 54-20°; 30-28°; 22-21° and 35-41°. Distance from margin 5 feet each way.

Grain

Olivine 8x6; 8x7; 8x7, av. .24x.20

Feldspar 10x2; 12x2; 14x2, av. .36x.06

Augite 26x10; 10x9; 12x8, av. .48x.27.

Sp. 15698. Hole 11 at 527 feet from surface. Coarser again; redder than 15696

Grain

Olivine 8; 8x6; 10x6

Feldspar 8x1; 16x2; 15x2, av. .39x.05

Augite 4x4; 26x13; 20x17; av. .50x.34.

Sp. 15465. Hole 10 at 121 feet from surface. Decomposed; no finer than 15464; andesite extinction angles 0, 0, 0, 0, 0. Distance from margin 2.

Grain

Olivine 8x5; 8x5, av. .26x.16

Feldspar 7x1; 14x2; 12x2, av. .33x.05

Augite 7x4.

11. 532-536; (Ss. 15699-15702 or 3).

10. 123-135; (Ss. 15466-9). MELAPHYRE, amygdaloidal; a trace (12) (2600 + 534) of sand at lower contact.

Sp. 15466. Hole 10 at 123 feet from bed rock surface. Finer amygdaloid; also trichitic; andesite extinction angles 0, 0, 6-6, 1, 0, 0; no augite. Distance from margin 0.

Grain

Olivine 5x3; 7x6; 9x6, av. .21x.15

Feldspar 15x2; 15x2; 13x1, av. .43x.05.

Sp. 15699. Hole 11 at 532 feet from surface. Amygdaloid; fine grained porphyrite; calcite; very thin section.

Grain

Olivine 3; 10x5?; 8x3

Feldspar 5x2; 3x.2; 6x.1, av. .14x.02.

Sp. 15467. Hole 10 at 124 feet from bed rock surface. Amygdaloid coarser grained; plagioclase extinctions 13-0; 1-2; 0-7; 8-5; 12-20; 0. Distance from margin 1.

Grain

Olivine 8x4; 12x5; 6x4, av. .26x.13

Feldspar 9x1; 15x2; 15x2, av. .39x.05

Augite 2x1; 2x1; 3x2, av. .07x.04.

Sp. 15700. Hole 11 at 533 feet from surface. Fine grained; decomposed with decomposed calcite.

Grain

Olivine 4; 5x4; 6x5

Feldspar 8x2 and varied.

Sp. 15701. Hole 11 at 534 feet from surface. Amygdaloidal; decomposed olivine; small not well marked amygdules.

Grain

Olivine 2; 3; 8; 9x7

Feldspar 12x1; 10x1; 15x2, av. .37x.04.

Sp. 15702. Hole 11 at 534½ feet from surface. Decomposed, slightly coarser; augite has a spherulitic habit. Feldspar ex. angles 17°-28°; 18°-20° and 3°-5°.

Grain

Olivine 7; 3; 3; 7

Feldspar 12x2; 6x1; 14x1, av. .32x.04

Augite 7x5; 4x2, av. .18x.11.

Sp. 15703. Hole 11 at 536 feet from surface. Porphyrite; microlitic, evidently marginal; glassy; trichitic. Distance from margin 0.

Grain

Feldspar ex. angles 18°-28°; 10°-8°; 15°-10°

Olivine 6x3?

Feldspar 10x2; 10x2; 10x3, av. .30x.07.

Sp. 15468. Hole 10 at 133 feet from bed rock surface. Poikilitic polysomatic augite; labradorite extinctions 29°; 17°-14°; 33°-25° and 9°. Distance from lower margin 2 ft.! The grain is extra coarse for this distance and suggests some error.

Grain

Olivine 7x7; 9x4; 9x6, av. .25x.17

Feldspar 18x3½; 20x2; 17x2, av. .55x.07

Augite 20x18; 30x25; 3x18, av. .53x.59.

Sp. 15704 at 542 feet in No. 11 corresponds in some respects to this but the plagioclase seems a little more basic and I think it belongs to the next flow.

Sp. 15469. Hole 10 at 135 feet from bed rock surface. Pipe amygdule; porphyritic, microlitic; contact shows trace of sand. Distance from margin 0.

Grain

Olivine 7x4; 9x7; 6x3, av. .22x.14

Feldspar 12x2; 6x1,

Augite none.

This specimen shows the contact,—being divided into two parts with sandstone between. The one part is not so red and has one phenocrysts 36x12. The other (lower?) is blacker especially around the very numerous small amygdules.

11. 536-550½ (Ss. 15703?-15705) (13) (2600+547)

10. 135-148; (Ss. 15469-72). MELAPHYRE, amygdaloidal ophite; more compact in the lower 4 feet.

Sp. 15470. Hole 10 at 138 feet from surface. Granules of altered yellow red olivine; plagioclase extinctions 0-6°; 0; 0. Distance from margin 3.

Grain

Olivine 10x8; 10x9; 12x9, av. .32x.26

Feldspar 16x2; 16x1.

Augite 12x11; 13x8; 12x4; .37x.23,

Sp. 15704. Hole 11 at 542 feet from surface. Poikilitic augite; feldspar ex. angles 26°; 39°; 17°- -13° and 42°-41°; 39°-44° and 27°; 30°-32° and 41°. Distance from margin 6.

Grain

Olivine 12x7; 9x6; 6x5, av. .27x.18

Feldspar 13x2; 12x2; 9x1.25, av. .34x.05

Augite 10x5; 10x10; 13x9; 18x12, av. .42x.30.

Sp. 15471. Hole 10 at 144 feet from surface. Poikilitic ophite 20 and 35-36; labradorite extinction 15-17° and 35-39°; 31-32° and 43°. Distance from margin 4 ft. from below?

Grain

Olivine 10x5; 9x6; 10x5, av. .29x.11

Feldspar 15x2; 17x2; 14x3, av. .46x.07

Augite 65x30; 32x25; 50x25, av. 1.47x80.

Sp. 15472. Hole 10 at 148 feet from surface. Sand seam; margin porphyritic; feldspar extinctions generally very small in this section; 18-20; 0. Distance from margin 0.

Grain

Olivine 8x4; 8x7; 9x9, av. .25x.20.

Sp. 15705. Hole 11 at 550 feet, the bottom of the hole being at 550½ feet, looking as though also near bottom of flow. Much decomposed poikilitic calcite and olivine. Distance from margin 14 above.

Grain

Olivine 8; 5; 6; 9x4

Feldspar 23x2; 18x2; 14x4, av. .55x.08

Augite decomposed.

148-169; (Ss. 15473-8). Melaphyre, ophite; upper 9 feet (20) (2600+567) amygdaloidal, then more massive.

Sp. 15473. Hole 10 at 153 feet from surface. Slightly poikilitic.

Grain

Olivine av. 10x8

Feldspar 18x2; 20x2; 22x4, av. .60x.08

Augite 30x12; 40x30; 60x12, av. 1.30x.54.

Sp. 15474. Hole 10 at 158 feet from surface. Poikilitic; much calcite replacing or interstitial; very feldspathic, extinction 24°-26° and 38°-35°; 4°-6° and 31°-35°. Distance from upper margin 10 ft., lower 11?

Grain

Olivine 8; 9; 9, av. .26

Feldspar 16x3; 23x2; 18x3, av. .57x.06. Also lamellae with same ex. but greater refringence 19°-13? w 42-36; 20-21 w 30-35; 18-18 w 40?-41; 21-25 w 39-37

Augite 34x40; 80x60; 30x25; 44x40, av. 1.46x1.19.

Sp. 15478. Hole 10 at 169 feet from surface. Contact with sediment very calcareous. Distance from margin 0.

10. 170-193; (Ss. 15478-88). (22) (2600+589)

This conglomerate contains abundant acid pebbles, of porphyry and felsite, and of melaphyre as well. This bed I took to be the conglomerate opened by the Island mine, as the two have a similar lithological look or character, and lie nearly in line of strike from each other. The Island mine conglomerate runs about 500 feet south of the north quarter post of Sec. 29, T. 64, R. 37, and has, considering its position, a steep dip (from 19° to 25°). Again, near Siskowit Lake, 50 steps north of the southwest corner of Sec. 26, T. 65, R. 36, and down to the corner, we find along the same line of strike a conglomerate which I take to be the same. So it continues on, but does not pass through to Conglomerate Bay, but like other beds in this vicinity veers a little to the north and goes through the trough of Rock Harbor. It is barely conceivable that, if we turn and go in the other direction, by the time we shall have

come to Grace Harbor all the overlying traps will have run out, and that this conglomerate will have merged in the general conglomerate of Cumberland Point. This conglomerate in drill hole No. X differs from those above it in that it carries a greater proportion of basic pebbles, especially of the immediately underlying melaphyre porphyrites, but it differs still more decidedly from any conglomerate within the first thousand feet beneath it, in that it still contains a considerable proportion of felsitic debris—more perhaps at the Island mine than at the drill hole. This contrasted relation of the conglomerates above and below this horizon holds good, so far as the meagre facts indicate, for the corresponding beds at the other exposures above mentioned. All these exposures, moreover, lie on the southeast flank of a fairly continuous ridge which is principally made up of the rocks which we have described as melaphyre porphyrites, the "ashbed" type of diabase. Northwest of this porphyrite ridge we find a still more continuous ridge, the "backbone" of the island, which is made up of very coarsely lustre-mottled ophites. It will be noticed, from what we have said, that not only the sedimentaries but the eruptives change their character, above and below the conglomerate horizon which we are studying. Above it we have a series of thin flows, generally largely amygdaloidal, but when coarse enough showing the mottling of the ophites, and interstratified with them numerous beds of silicious sedimentary rocks. Below it, as we shall see, the beds are in general thicker and more massive, and less augitic (porphyrites, that is sodic melaphyres), and the interstratified sediments and amygdaloids resemble those which form the hanging of the Ashbed type.

Now we have on Keweenaw Point at Eagle River and elsewhere (Figures 23-38) a series precisely similar in stratigraphic order, only with the order from southeast to northwest reversed. I used mainly for comparison Marvine's Eagle River section, Fig. 34, as it was the most complete section made when I did my Isle Royale work, and I went over and revised it and collected specimens from it expressly for this purpose. Beginning from the uppermost trap bed actually noted (Geol. Sur. of Mich. I, Pt. II, p. 112) Marvine counts ten sandstone in the first 2,300 feet of the section horizontally, (i. e., 1,272 feet thick; *loc. cit.*, p. 24) to bed No. 35. This is the greater part of his series (c) which he however carries down somewhat farther to the first scoriaceous amygdaloid. In this part of the series the beds incline to be lustre mottled when at all thick, and the character of the formation generally matches the beds above the Island mine conglomerate. It will be noticed that for this part of the section we have on Isle Royale but half the thickness represented at Eagle River, the thickness to the bottom of the Island mine conglomerate being but 589 feet, but on the other hand we have six to eight representatives of the ten conglomerates and sandstones.

Beginning with the flows immediately below Marvine's bed No. 35 and the Island mine conglomerate, we find a distinctly less augitic character in the flows as a whole, while the base of each flow remains somewhat ophitic in texture; we can recognize this change under Marvine's bed No. 35, (Fig. 34), in the Copper Falls adit, Fig. 30, in the Tamarack mine No. 5 shaft section at 185 feet? (Belt 4) Fig. 37, and elsewhere. In my re-examination of the Eagle River section I observed the change there at the point indicated. Then in all cases the first sedimentary bed we meet below the Island mine conglomerate, respectively below Marvine's bed No. 35, Tamarack belt 5 is distinctly of the Ashbed type, e. g., at 415 feet in No. X, Marvine's bed No. 44. Below this bed the traps are still less augitic, and they, together with their associated scoriaceous conglomerates, have in each case about the same thickness. Under this complex we find also, both on Isle Royale and on Keweenaw Point, the largest flow of the coarsest ophite that occurs anywhere in the series, the Greenstone.

Now I am well aware of the danger of purely lithological correlations, but in view

of the fact that beds of the series which we have been studying have been followed for a distance along Keweenaw Point equivalent to that across the lake, in view of the fact that a basic lava sheet like the "Greenstone" of 200 feet, yes, in some places as in the Manitou section (Fig. 29) of 1,130 feet thickness and more, may be expected to spread a great distance, with some uniformity of lithological character, and in view of the general parallelism both in sedimentaries and in traps, both above and below, there seems to be no reasonable doubt that the Island mine conglomerate is equivalent to Marvine's bed No. 35, or is, at least, at very nearly the same horizon, and marks the same moment of quiescence in volcanic activity.

Sp. 15479. Hole 10 at 170 feet from surface. Pebble? with spherulitic open textures.

Sp. 15480. Hole 10 at 172 feet from surface. Pebble; quartz porphyry, with poikilitic ground mass very calcareous and oligoclase phenocrysts.

Sp. 15481. Hole 10 at 174 feet from surface. Pebbles of quartz porphyry with aureoles in the ground mass, or possibly secondary micropoikilitic quartz oriented with the phenocrysts.

Sp. 15482. Hole 10 at 177 feet from surface. Pebbles of andesitic porphyrite with altered olivine? microlitic. This is a basic type of rock not noticed in the conglomerates above.

Sp. 15483. Hole 10 at 181 feet from surface. Oligoclase porphyrite; poikilitic ground, i. e., felsitic.

Sp. 15484. Hole 10 at 182 feet from surface. Pebble of altered fine grained melaphyre.

Sp. 15485. Hole 10 at 186 feet from bed rock surface. Microlitic, oligoclase porphyrite pebble.

Sp. 15486. Hole 10 at 188 feet from surface. Decomposed glass! Phenocrysts of oligoclase, this type of pebble not noticed above. Olivine.

Sp. 15487. Hole 10 at 191 feet from surface. Poikilitic quartz porphyry and porphyrite fragments.

Sp. 15488. Hole 10 at 192½ feet from surface. Quartz porphyry with micropoikilitic ground.

193-306; (Ss. 15489-15501). MELAPHYRE, porphyrite. This is a (110) fpseudamygdaloid for the first 20 feet, that is, the amygdules are indistinguishable from decomposition spots. It is different from the ophites above, most markedly in microscopic characters, but also to the naked eye, for the feldspar is much more conspicuous and there is no lustre-mottling, as there would be very plainly in a bed of ophite of equal thickness. In other words the feldspar is large in proportion to the size of the augite. Light greenish seams and spots, and a generally lighter, more greyish green color may be noted on comparison. This would correspond to Marvine's bed No. 36.

The grain of the augite is plotted as t in Fig. 16 of the Isle Royale Report. It will be noticed how low the rate of increase is,—about 1 mm. in 50 feet or 0.000065.

It will be noticed in Marvine's description of bed No. 36 that the scoriaceous character of the amygdaloid is mentioned which is characteristic of the less augitic melaphyres. This has just about the same thickness and petrographic character with T. 5 b. 8. Annual Report for 1903, p. 254. The feldspar is oligoclase instead of labradorite.

Sp. 15489. Hole 10 at 193 feet from bed rock surface ex. 0; 0; 12°-12°; 0; 0; Not exactly at margin; large olivine; decomposed, little augite; *oligoclase very* decomposed. Distance from margin 0.5? ft.

Grain

Olivine 23x18; 16x10; 8x4; 17x12 av. .56x.40;

Iron oxide growth?, also Octahedra 1. and 2.5

Feldspar 16x4; 22x6; 36x6, av. .74x.16.

Sp. 15490. Hole 10 at 198 feet from bed rock surface. Magnetite apparently surrounded by zones of altered olivine? Olivine and augite really count as a unit in texture; chalcedonic cavities; feldspar Ab_5 An_3 extinctions 10°-12°; 9°-8°w 1°. Distance from margin 5.5.

Grain

Olivine 7; 8; 17, av. .32

Iron oxide 2.5; 10x9; 8x7; 17x15, av. .35x.31

Feldspar 40x5; 40x7; 28x6, av. 1.08x.18

Augite 9x5; 12x7; 15x6; 12x5; 16x8, av. .42x.20.

Sp. 15491. Hole 10 at 214 feet from surface. Zeolitic amygdaloid; so little augite that it is discontinuous; andesite feldspar extinctions 6°-10°; 7°-7°; 9°-8°; 5°-4°.

Grain

Olivine 10; 7x3; 8x7; 16x9

Iron oxide 7x6; 9x9; 14x12, av. .30x.27

Augite 23x12; 13x12; 46x13, av. .82x.37.

The augite is not far from the same size as 16834 at 15665, the olivine larger but not apparently more abundant.

Sp. 15492. Hole 10 at 224 feet from bed rock surface. Very coarse; augite patches are discontinuous; porous texture with secondary filling; the cavities have very sharp feldspar? crystals; the olivine is decomposed to bowlingite (see Fig. 23, p. 155 of Isle Royale report repeated here as Fig. 16), as A. N. Winchell thinks it should be called rather than iddingsite[1]; feldspar much altered.

Grain

Olivine 23x22; 30x16; 32x27, av. .85x.65

Iron oxide 30x20; 14x12; 25x15, av. .69x.47

Feldspar 60x12; 70x10; 65x11, av. 1.95x.33

Augite 30x28; 55x40; 45x30, av. 1.30x.98.

Sp. 15493. Hole 10 at 225 feet from surface. Olivine and magnetite make up grains together in apparently primary intergrowth; porous to the naked eye; feldspar appears 2-3 mm. long; extinction angle 0-5, w10-8.

Grain

Olivine 30x17; 17x12; 28x28, av. .75x.59

Iron oxide 23x22

Feldspar 79x10; 70x10; 65x5, av. 2.14x.25

Augite 54x32; 73x47; 68x45, av. 1.95x1.24.

See I. R. report Plate VI (p. 162) Fig. 3. This section well in from the margin and coarse illustrates the doleritic texture in which chlorite coatings seem to wrap around the feldspar and line the walls of cavities.

Sp. 15494. Hole 10 at 231 feet from surface. Sharp crystals of Manebach and Karlsbad twins combined with the Albite law. Extinction angles 12-8° with 16°-12°; 9-12°w14-15° and 19-3w13- (-1°); andesite Ab_{60} An_{40} augite in patches of granules; the olivines are larger and fewer, the augite less and the feldspar less basic than in the beds above the Island Mine Conglomerate. Distance from upper margin 37.

Iron oxide 20x15; 30x23; 25x23, av. .75x.61

---

[1]American Geologist 23 (1899) p. 43; id. 1900, p. 211-212; Optical Mineralogy, p. 359.

Feldspar 87x7; 70x8; 90x8, av. 2.47x.23

Augite 35x20; 40x30; 44x40, av. 1.19x.90.

Sp. 15495. Hole 10 at 233 feet from surface. Albitic margin zones; Karlsbad twins abundant; ex. 13°-4°; 4°-6°w14°; the augite less, the feldspar generally less basic. Distance from margin 39.

Grain

Olivine 40x20; 80x38; 50x20, av. 1.70x.78

Feldspar 130x10; 150x16; 140x30, av. 4.20x.56

Augite 150x70; 84x50; 40x36, av. 2.74x1.56.

Sp. 15496. Hole 10 at 243 feet from surface. Mainly changed to a green stuff, see discussion of chloritic alteration, augite left in patches through the chlorite. Distance from margin 48 ft. from above.

Grain

Olivine 20x16; 30x20; 24x24, av. .74x.60

Iron oxide 26x26; 16x14, av. .70x.66

Feldspar 130x10; 30x16, av. .10x.46.

Sp. 15497. Hole 10 at 250 feet from surface. Olivine changed to iron oxide and it is hard to tell if the iron oxides are not all after olivine. Distance from margin 54 (about middle).

Grain

Olivine 38x18

Iron oxide 40x28

Feldspar 58x3; 70x15; 53x10, av. 1.81x.28

Augite 28x25; 54x34; 45x27, av. 1.27x.86.

Sp. 15498. Hole 10 at 260 feet from surface. More compact; feldspar extinctions 17°-11°; 0°; 11°. Distance from lower margin 44 ft.

Grain

Olivine 18x12 12x9; 11x8, av. .41x.29

Feldspar 60x12; 60x5; 35x5, av. 1.55x.22

Augite 29x18; 35x18; 28x18, av. .92x.54.

Sp. 15499. Hole 10 at 272 feet from surface. Many miarolitic cavities filled with chalcedonic quartz, chlorite, etc., like the photograph of 15490. Of this section a large number of extinction angles for albite—Karlsbad twins were measured together with their birefringence. This varied sometimes from center to margin, but characteristics extinctions were 17° on each side for one and 36° on each side for the other set of lamellae in a compound albite Karlsbad twin. The feldspar must be near Ab_{40} An_{60}, distinctly more limey than at the top. This is in harmony with the tendency elsewhere noted for the lime to segregate into the lower and later cooled part of a flow.

Distance from margin 33.

Olivine 19x11; 12x12; 13x13, av. .44x.36

Feldspar 30x8; 43x10; 35x5, av. 1.08x.23

Augite 20x20; 15x12; 20x8, av. .55x.40.

Sp. 15500. Hole 10 at 284 feet from surface. Though the feldspar is getting basic the augite is still small in quantity; the rock coarse grained with coated cavities lined with chalcedony and chlorite; of a large number of extinction angles measured 9°-13° with 12°-25° may be taken as representative. The feldspar is near Ab_{50} An_{50}. Distance from margin 21.

Grain

Olivine 14x13; 25x20; 12x10, av. .51x.43

Augite 37x20; 26x18; 20x11, av. .83x.49.

Sp. 15501. Hole 10 at 299 feet from surface. Feldspar extinctions 19°-17°; 12°-9°; 5°-13°w0°; 8°-11°; 9°-8°; 6°-4°; 16°-16°w10°. Distance from margin 7.

Grain

Olivine 20x18; 30x20; 13x10, av. .63x.48

Augite 10x7; 18x10; 7x5, av. .35x.22.

306-322; (Ss. 15502-5). Amygdaloid. This is a fine grained (16) (126) red amygdaloid, apparently the same kind of rock as the bed above, but a thinner flow.

Among the drillings at 321 feet were 2 inches; at 322 feet, 4 inches; at 323.3 feet ½ inch of a basic Sandstone. The driller's record threw no light on the occurrences, but from the gradually finer grain of the traps above and below them, I am led to believe that they all really belong at 322 feet, and that there is a bed of fine grained dark red basic sandstone there. Dip 14°. They may, however, be clasolitic in nature and similar material is found in T. 5 b. 11, and T. 5 b. 12 is a conglomerate. This must nearly correspond to T. 5 b. 11, Marvine's bed 36.

Sp. 15502. Hole 10 at 306 feet from bed rock surface. Microlitic porphyritic amygdaloid with sand in cavities also glass fragments. Feldspar extinctions 9-8°; 8-8°; 12-18°.

Sp. 15503. Hole 10 at 308 feet from surface. Pretty thoroughly decomposed; there is a secondary poikilitic texture visible in polarized light; without the analyzer it appears a microlitic amygdaloid.

Sp. 15504. Hole 10 at 311 feet from bed rock surface. Coarser somewhat and with very little augite; olivine rare; same type as flow above; feldspar extinctions 15°-11°; 14°-8°w5-8°.

Grain

Olivine 8x7; 7x4; 8x7; 14x10, av. .30x.23

Feldspar 40x4; 25x6; 30x4, av. .95x.14

Augite 12x11; 30x7; 18x10; 25x15, av. .70x.35.

Sp. 15505. Hole 10 at 321 feet from bed rock surface. Sediment; basic; poikilitic cement; at 321, 2 in., 322, 4 in., 323½ of what looks to me tufaceous material. Sandstone. Compare T. 5 p. 12.

322-325; (S. 15506). Perhaps another bed of Melaphyre. At (3) (129) 325 a narrow seam is noted which may be a small fault.

Sp. 15506. Hole 10 at 325 feet from surface. Abundant altered olivine; much marked poikilitic augite; feldspar ex. 13°-17°w33°-38°; 28°-26°; 20-w28-34; 18°-19°; 35°-35°; 41°w29°-16°; 12°-24°w29°-42°; this section is distinctly a lime melaphyre and not close to the margin either, (at least 10 or 20 feet from it). So that if there is not a mistake in the drill samples we must assume a fault here. Compare 16401 to 16403 of the Tamarack section; ophite.

Grain

Olivine 12x9; 13x8; 15x9; 5x5, av. .37x.25

Feldspar 22x2; 20x3; 24x3, av. .66x.08

Augite 62x40; 56x35; 120x70, av. 2.38x1.45.

325-332; (Ss. 15506-8). Amygdaloid; at 332 feet highly amygdaloidal (7) (136) brecciated, and mixed with finer grained sediment; quite likely a slip. Compare Eagle River bed 37.

Sp. 15507. Hole 10 at 329 feet from bed rock surface. Similar to 15506 but finer grained as to the augite and more feldspathic; feldspar ex. 11°-13°w38°-30°; 10°-27°; 18°-23°; 34°-32°w31°-18°; 30°-30°w20°-20°; 12°-8°w4°.

Grain

Olivine 22x10; 22x8; 22x19, av. .66x.37

Feldspar 32x3; 25x5; 28x4, av. .85x.12

Augite 30x18; 30x14; 50x30, av. 1.10x.62.

Evidently, comparing 15506 and 15507, we have but the bottom of a flow represented.

Sp. 15508. Hole 10 at 332 feet from bed rock surface. All altered; a contact of two flows; (1) amygdaloid and porphyritic in a glassy not microlitic ground; (2) sandstone streak between; (3) amygdaloidal microlitic and porphyritic.

Grain

Olivine 12x8? none; 28x17; 20x12, av. .60x.37

Iron oxide much

Feldspar 20x4; 12x2; 30x12, av. .62x.18

Augite none; glass.

In this section were sharp crystals of prehnite in an amygdule as shown in Fig. 24 of Vol. VI, Part I). It has high refringence, birefringence at least as great as quartz, and ex. 0°. The whole rock below is thoroughly altered to prehnite, the feldspar forms being replaced by it.

332-338; (Ss. 15508-12). AMYGDALOID. (6) 140?

The probability is that this horizon which is that of Eagle River beds 36-43, grouped by Marvine together for description, was one of those porous beds particularly likely to be crushed and faulted, for in the various sections one cannot make close correlations and yet there is a general similarity. Even the prehnitic alteration of 15508 and 15509, we find not only here but also mentioned by Marvine.

Sp. 15509. Hole 10 at 333 feet from surface. Microlitic porphyritic amygdaloid in contact with sandstone; There are olivine pseudomorphs probably but the rock is all changed to prehnite.

Grain

Olivine? 27x23, 25x15, av. .86x.63

Feldspar ? 40x20; 15x5, av. .91x.50.

Sp. 15510. Hole 10 at 336 feet from surface. Very little augite left; altered olivine; much feldspar, extinctions 9°-27° w 2; 7° all; 11°-4°; 6°-4°; 10°-5° w 4°; 10°-8° and 12°; 13°-14°; 16°-12°; there appears to be bastite after olivine, good cleavage + ex 0°, but compare bowlingite.

Grain

Olivine 8x5; 8x6; 19x8, av. .35x.19

Feldspar phenocrysts 36x15; 34x4; 50x16, av. 1.10x.35 mm.

Augite 14x12? av. .42x.36?

Sp. 15511. Hole 10 at 337 feet from surface. Altered olivine as before; andesite ex. 20°-10°; 15°-5° and 4°; 18°-12° w, 16°; 2°, 8°.

Grain

Olivine 17x10; 22x18; 12x10, av. .35x.19.

Feldspar phenocrysts 32x10; 32x8; 13x13, av. .77x.31 mm.

Sp. 15512. Hole 10 at 338 feet from surface. *Porphyritic;* secondary poikilitic; microlitic; andesite ex. 17°-11°.

Grain

Olivine 10x10; 13x9; 14x10, av. .33 mm.

Feldspar phenocrysts 12x3; 25x17; 26x18, av. .63x.38 mm.

338-415; (Ss. 15513-24). MELAPHYRE; of the porphyrite type (77) 217 at the top, but becoming darker and approaching the ophite type at the bottom. It is somewhat amygdaloidal down as far as 352 feet, beginning as a fine grained red porphyrite with amygdules of chlorite and a few of agate at the top. At 344 feet and 377 feet green rock was cut which would in the field prove, I feel sure, to be either rounded masses ("inclusions" or "bombs") or irregular skeins, which are characteristic of this group, and are slightly more likely to be amygdaloidal than the

adjacent rock. They are more decomposed, though this decomposition doubtless follows some primary feature, and they are permeated with cavities lined with crystals of quartz and chlorite.

As we get toward the bottom the rock, which is firm and compact, and yields long drill cores and would make good road metal becomes darker, and finally somewhat lustre-mottled. This is true not only on Isle Royale, but at Eagle River and in the Tamarack shaft. *Copper* appears in paper-like sheets in the chlorite seams. This is probably the Eagle River beds Nos. 40-43. Compare T. 5 b 9-10 flow 6. Analyses of this bed will be found in Tables XII and XIII of Chapter II, and illustrates again the tendency toward accumulation of lime in the lower and last crystalized part.

Sp. 15513. Hole 10 at 339 feet from surface. Like 15512 but red microlitic; 339-415 trap.

Grain

Olivine 12x10; 13x10, av. 0.33 mm.

Feldspar porphyrite 20x10; 30x10; 30x10, av. 0.80x.30 mm.

The grain of the augite and feldspar of this sheet are illustrated in Fig. 22 of the Isle Royale Report and the variation in the character of the feldspar in Plate V of that report.

Sp. 15514. Hole 10 at 344 feet from surface. Microlitic; porphyritic; much decomposed; well marked grains of altered olivine.

Grain

Olivine 13x8; 10x10; 10x8, av. 0.30

Feldspar phenocrysts 49x10?; 25x5; 30x25, av. 0.98x0.40.

Sp. 15515. Hole 10 at 350 feet from surface. Somewhat patchy augite but much feldspar, ex. 0-11°; 8-7°; 15-5°; 0-0; more basic at bottom of flow. Distance 9 feet from top?

Grain

Olivine 28x16; 16x5; 18x10, av. 0.46

Feldspar phenocryst 30x10; 32x9; 37x8, ave. 0.94x0.27

Augite 40x30; 30x20; 28x15, av. 0.64.

The feldspar is shown on Plate V of Vol. VI as a. It is Ab_{85} An_{15}.

The analysis by F. P. Burrall is given in Chapter II.

The proportion of different minerals were compiled by me on the basis of minerals actually seen in Vol. VI, p. 146. They were recalculated by A. N. Winchell[1].

	W.	L.
Ortho	6.12	3.47 + 2.6
Ab.	28.82	34.06
An.	24.19	18.07
Nephelite	2.84	0.
Diopside	3.80	10 35
Hypersthene		5.14 fassaite
Olivine	23.25	17.44
Magnetite	3.94	3.94
Hematite	0	0
Ilmenite	0	0
Apatite	0	0
Calcite		.90
H_2O	5.01	
	98.87	

[1] Jour. Geol. XVI. (1908) p. 771.

The main difference comes from my allowing a certain amount of alumina in the augite so that Winchell gets 61.97% of salic minerals including a little nephelite, while I got 55.60 of feldspar including no nephelite.

Sp. 15516. Hole 10 at 354 feet from surface. Thoroughly decomposed; about same grain as 15515. Distance 16 feet from top.

Grain

Olivine?

Feldspar 30x15; 25x7; 23x8, av. 0.78x0.30

Augite 30x20; 40x35?; 25x20, av. 1.48 to .78.

The augite is shown merely by scattered fragments left in alteration and may be coarser. The alteration is into a mass of minute yellow epidote prisms.

Sp. 15517. Hole 10 at 358 feet from surface. Poikilitic augite; slightly decomposed; andesite (Ab_{60} An_{40}) extinction angles see Plate V letter b) 21-16° and 3°; 6-5° and 16°; 0; 0°; 6; 12°; 13°; 4-5. Distance from margin 20 ft.

Grain

Olivine 15x12; 19x16; 20x15,av. 0.48 mm.

Feldspar 50x4; 40x4; 35x8, av. 1.25x0.16 mm.

Augite 80x40; 23x22; 80x47, ave. area $(.47)^2$ or $(1.43 \text{ mm.})^2$

There is not much augite and this is of the feldspathic ophite type.

Sp. 15518. Hole 10 at 365 feet from surface. Poikilitic augite; much decomposed olivine; feldspar abundant; augite much cut up; very small extinction angles 0°, 0°, 0°, 0°, 0°. Distance from top 27 ft. from bottom 50 ft.

Grain

Olivine 33x18; 16x10; 40x18, av. 0.67 mm.

Feldspar 42x5; 35x8; 37x4, av. 1.14x0.17 mm.

Augite 150x80; 40x40; 100x65, av. $(2.3)^2$ mm.

Sp. 15519. Hole 10 at 372 feet from surface. Very poikilitic augite; low angled feldspar. Distance from lower margin 40½ ft.

Grain

Olivine 25x15; 18x8; 25x20, av. 0.55 mm.

Feldspar 28x8; 40x10; 40x10, av. 1.08x0.28

Augite 50x50; 260x260; 120x90, av. $(4.45 \text{ mm.})^2$

See Vol. VI, Pt. I, p. 130 fig. 16

See Vol. VI, Pt. I, p. 144 fig. 22

From this point on the grain of the augite is plotted on Fig. 16 of the Isle Royale report, as well as on Fig. 22; under the letter s. The rate of increase from the bottom up is well up to the high figures of 1 mm. in 10 feet, or .00033. The composition is that of a lime melaphyre as shown by the analysis by F. P. Burrall[1].

It may be a coincidence that this specimen which has the coarsest augite has also the most lime, since it also has most (CO_2) but it quite harmonizes with my theory of the concentration of lime in the last formed rock.

Sp. 15520. Hole 10 at 378 feet from surface.

Pretty much all decomposed; coarse; chloritic like 15519. Distance from lower margin 36 feet.

Grain

Iron oxide 32x32; 27x25; 14x14, av. 0.72 mm.

Feldspar 92x10; 120x8; 80x8, av. 2.92x0.26 mm.

In this section there was no olivine but there were beautiful triangular iron oxide skeletons which replace it as an element of the fabric.

Sp. 15521. Hole 10 at 380 feet from surface. Prehnite vein; labradorite. ex.

---

[1]Vol. VI., p. 143, and above Chapter II, p. 114.

2w24-29°; 22-23; 6-6w23-23 letter c of Plate 6 of the Isle Royale Report; decomposed but high angled feldspar; chloritic rinds around feldspar. Distance from lower margin 25 feet.

Grain

Olivine 43x40

Iron oxide 42x30; 40x25, av. 1.00 mm.

Feldspar 50x13; 42x6; 42x9, av. 1.34x.28 mm.

Augite 120x80; 100x86; 180x120 av. area 3.4 mm. by micrometer. The patches look about 2 to 3 mm.

Sp. 15522. Hole 10 at 403 feet from surface. Contact of poikilitic melaphyre with fine grained sediment (8, 4, 4, 2, 2, 2) or clasolite which the grain shows is evidently infiltered into a crack of the lava. Labradorite extinctions 10°-w33°-34°; 11°-18°w29°-34°. Distance from margin 12.

Grain

Olivine 27x22; 24x15; 20x20, av. .61

Feldspar 40x15; 38x7; 30x4, av. 1.08x0.26

Augite 90x56; 160x50; 100x75, av. area (2.6 mm.)^2.

Sp. 15523. Hole 10 at 406 feet from surface. Labradorite ex. 24°-20°w42°-39°; 24°-23°; 19°-18°; 37°-33°; 24°-20°w-32°; 28°w40°.37°. Distance from margin 9. The grain is plotted in Figures 16 and 22 of the Isle Royale Report.

Grain

Olivine 40x30?; 40x30; 24x18, av. 0.91 mm.

Feldspar 22x3; 40x10; 40x8, av. 1.02x0.21 mm.

Augite 120x80; 110x84; 160x100, av. (2.2 mm.)^2; apparently 2-3 mm. patches to the eye.

The composition of this has been subject of analysis by F. P. Burrall and of study by Winchell and myself. Winchell gives the norm. I estimate the mode.

	W	L
Orthoclase	6.12	1.87+1.2
Albite	23.58	21.48
Anorthite	30.30	34.19
Nephelite	4.26	
Diopside	18.41	19.50
Fassaite		5.62
Olivine	2.10	6.02
Magnetite	11.14	6.72
Cc	2.30	
H_2O	3.49	

We both agree in making a decided increase in augite as compared with 15515.

Sp. 15524. Hole 10 at 415 feet from surface. This like 15522 shows sediment, yet the grain is so coarse that it is not a normal margin. There must either be faulting or some sediment enclosed from the bed below. The augite is, however, so much finer in grain that less than 10 feet need be allowed for margin planed away. a. poikilitic; with olivine; b. sediment. Distance from margin 0+?

Grain

Feldspar 32x7; 40x5; 30x7, av. 1.02x0.19 mm.

Augite 30x20; 20x20; 24x1.6 av. (0.65 mm.)^2. The augite patches appear about 1 to 2 mm. across to the eye.

(217)

415-426; (Ss. 15525-30). CONGLOMERATE 17. This bed is the first of (11) (228) the scoriaceous or amygdaloid conglomerates, otherwise known as ashbeds or scoriaceous amygdaloids. The matrix is very dark, of a deep maroon shade, generally

speaking, very fine grained and argillaceous, and the pebbles are irregular masses of amygdaloid, like the beds with which they are associated. The line between the conglomerate and the underlying amygdaloid is extremely difficult to draw. This is the reason why these scoriaceous beds have been considered as extreme forms of amygdaloid, but there is no doubt that in the beds which I am now considering there is a large amount of detrital matter, almost exclusively from basic rocks. They are very calcareous.

This conglomerate corresponds very nicely to Marvine's Conglomerate 18, Eagle River bed No. 44- as well, indeed, as his bed No. 35 corresponds to the Island mine conglomerate, also to T. 5 b 4 of (Fig. 37). The underlying rock corresponds to Marvine's bed No. 45, being a melaphyre porphyrite, with a clean conchoidal fracture, as we shall see, and the immediately overlying bed is in each case a mottled ophite below, a porphyrite above. Marvine allowed eight beds between No. 35 and No. 44, but two numbers were allowed for beds unobserved, and none of the observations showed that Nos. 42 and 43 were separate beds, and in fact I inferred from the coarseness of grain and other things that in reality from No. 39 down to No. 43 was all one large flow (184 feet) corresponding so closely to our melaphyre in No. X (338-415, i. e., 75 feet thick) as probably to be the same flow. That left four beds in the Eagle River section, between No. 35 and No. 44, to correspond to our six beds, in each case with a thick flow at the base. From the top of Marvine's bed No. 35 to the top of his bed No. 44 is, according to Marvine, 273 feet. The corresponding distance in our column of rocks is (806-567) 239 feet, which is quite as close a correspondence to the general ratios as could be expected, 50 miles away, and eminently satisfactory. The correlation is made much stronger by the study of the comparative coarseness of grain, and the change in the character of the feldspar. Marvine's Conglomerate 18 is by his Portage Lake section (atlas Plate XIX) 370 feet above the Hancock West or No. 17. In the Eagle River section there is (86+1810=1503) 393 feet. Here the distance is 239 to 283 feet,—in harmony with the general shrinkage of the beds on Isle Royale. This would then mark the line between Marvine's group (b), and his group (c) the Eagle River group, and the Ashbed group.

Sp. 15525. Hole 10 at 416 feet from surface. Poikilitic, calcareous sediment; altered ash?

Sp. 15526. Hole 10 at 417 feet from surface. Poikilitic; calcareous cement; small grains.

Sp. 15527. Hole 10 at 418 feet from surface. Margin composed of material as in 15526 with large red stained fragments of microlitic amygdaloid.

Sp. 15528. Hole 10 at 419 feet from surface. Mixed sediment and amygdaloid; this corresponds to the ashbed.

Sp. 15529. Hole 10 at 425 feet from surface. Probably contact of underlying flow; fragments porphyritic amygdaloid, microlitic; this corresponds to the ashbed.

ASHBED GROUP.

Marvine's (b)

10. 426-483; (Ss. 15531-7). Melaphyre, or olivinitic augite, por- (56) (56) phyrite, Tobin Porphyrite. This is one of the most acid of the melaphyres, really of the type of an olivinitic augite andesite. The smoother fracture, generally lighter, green color, abundance of not very large white porphyritic feldspar aggregates, and compact texture are well marked. This is the bed that we seem to find at the top

of drill hole No. IX. and have called the Tobin porphyrite, Eagle River bed 45. It is also well defined in the Tamarack shafts T 5, No. 5 of Fig. 37.

We assume that No. X, 483 feet, is equivalent to No. IX, 49 feet, a difference of 434 feet. Subtracting the excess of altitude of No. X over No. IX (206.7-202.5), 4.2 feet, we have 430 feet, which divided by the distance between them along the line of cross-section, 1973 feet, gives 0.217, the tan 12° 20′. This is the same dip we had before.

Sp. 15530. Hole 10 at 426 feet from surface. Scoriaceous; the same as No. 15529; porphyritic feldspar crystals have extinctions 15°-12°; 6°-7°; 14°-4°.

Grain

Feldspar 40x28 and 8x1, av. .80x.48.

However, we should point out the strong resemblance of the rocks around No. X, 483 feet; No. IX, 385 feet; No. VIII, 47 feet, in order that any one may, if he choose, try his hand at making them the same horizon repeated. I have been unable to do so without assuming arbitrary and unnecessary faults *ad libitum*.

Sp. 15531. Hole 10 at 431 feet from surface. Almost no olivine; microlitic amygdaloid such as the fragments in the conglomerate above; porphyritic crystals have extinctions 26°-4°; 18°-11°; 0; 0; 16-7; 4-6; 14-13; augite in grains; ground mass microlites.

Grain

Olivine 30x30; 32x23, av. 1.1x.88

Feldspar porphyritic crystals 32x17; 30x10; 30x17, microlites 8x1.5; 8x1.

Augite 1; 1; 1; 2x1.

Sp. 15532. Hole 10 at 432 feet from surface. Similar to 15531; olivine in occasional porphyritic grains; porphyritic feldspar extinctions are 16°w7°-15°; 6°-6°; 0°; 11°-18° and with higher birefraction 0°; glomeroporphyrite.

Grain

Augite 28x20; 17x7; 24x16, av. .59x.43

Iron oxide 5x4; 5x5; 6x1, av. .16x.10

Feldspar phenocrysts 20x3; 33x8; 40x18, av. .93x.29; microlite 10x2; 8x1; 8x1, av. .26x.04

Augite 10x3; 3x2; 3x3; 4x2, av. .16x.09.

Sp. 15533. Hole 10 at 445 feet from surface. Similar to 15531; markedly porphyritic; olivine in scattered grains only; a little augite in idiomorphic granules; glomeroporphyritic andesite ex. 12°-12w4°-5°.

Grain

Olivine 28x20; 17x7; 24x16, av. .69x.43

Iron oxide 5x4; 5x5; 6x1, av. .16x.10

Feldspar phenocrysts 20x3; 33x8; 40x18, av. .93x.29; microlites 10x2; 8x1; 8x1, av. .26x.04

Augite 10x3; 3x2; 3x3; 4x2, av. .16x.09.

Sp. 15534. Hole 10 at 452 feet from surface. All altered, leucoxene?, viridite? (+ex. 0), prehnite (-ex 0) and amphibole? faint outlines of small and large feldspar.

Grain

Olivine 8x7? 10x9, av. .3x.26.

Sp. 15535. Hole 10 at 463 feet from surface. Andesite extinctions 14°-11°; 0; 0; 16-7; 15-5. Distance from lower margin 19 feet.

Grain

Olivine 15x7; 45x33; 21x20, av. .81x.60

Feldspar phenocrysts 70x15; 40x13; microlite 12x2

Augite 7x5; 6x2.5; 8x1.5, av. .21x.09.

Sp. 15536. Hole 10 at 475 feet from surface. Much more ferruginous; feldspar extinctions 24°-15°; 12°-10°w26°-32°; prismatic augite. Distance from margin 10 feet.

Grain

Olivine 12x10; 17x10, av. .65x.33

Feldspar 50x20; 50x7; 40x10, av. 1.40x.37

Augite 6x2; 6x2; 6x5, av. .18x.09.

Sp. 15537. Hole 10 at 483 feet from surface. Olivine very rare; andesite extinctions 8°-8°; 10°-4°; 24°-11°; 15°-0°; 15°-13°; 13°-7°; augite in dishevelled sheaves.

Grain

Olivine 39x22; 22x20; 10x7, av. .71x.49

Feldspar phenocrysts 35x10; 45x8; 43x15, av. 1.63x.33

Augite 9x3; 6x5; 12x3, av. .27x.10.

Ss. 15386-9 from the top of No. 9 also belong to this flow. Sp. 15387 has feldspar whose extinction angles definitely indicate Ab An. Sp. 15388 seems less basic and augitic than 15387 and has some red smaller feldspar (3x.5) 2x.1). Sp. 15389 is similar.

There are scarce and not uniform distributions of pseudomorphs of olivine.

DRILL HOLE IX

We then correlate the first 49 feet of No. IX with the bed of melaphyre already described (Ss. 15386-9)

Sp. 15386. Hole 9 at 6 feet from surface. Low angled feldspar; ex. angles 9°; 0°; 14°; 0°; 0°; 0°; 22°-27°; 0°; 8°-15°-22°; two generations of olivine?

Grain

Olivine 33x20; .5x3; 7x6, av. .40x.29 mm.

Iron oxide 3x2; 5x6; 6x4, av. .14x.12 mm.

Feldspar phenocrysts 17x14; 36x14; 37x11, av. .90x.39 mm.

Augite 4x1; 10x4; 3x4, av. .17x.09 mm.

Sp. 15387. Hole 9 at 23 feet from surface. Low angled feldspars; phenocrysts 4°-4°w1°; 9°-9°; 5°-3°; 24°-20°; 23,-18°; 33°-24°; small decomposed olivine quite abundant?

Grain

Olivine 4x2; 5x5, av. .15x.11 mm.

Iron oxide 13x12; 15x12, av. .46x.40 mm.

Feldspar phenocrysts 100x15; 55x20; 54x30, av. 2.09x.65 mm

Augite 11x3; 18x9; 11x12, av. .40x.24 mm.

Sp. 15388. Hole 9 at 46 feet from surface. Low angled feldspars; ex. angles 9°-6°; 7°-0°; 0°; 0°; 11°-17°w0°; 11°-12°; 16°; rather less basic and augitic.

Grain

Olivine 28x25; 30x25, av. .96x.83 mm.

Iron oxide 3x1; 2x1; 3x2, av. .08x.04 mm.

Feldspar phenocrysts 22x16; 26x14; 43x30, av. .91x.60 mm.

Augite 2x1; 4x3; 3x2, av. .09x.06 mm.

Sp. 15389. Hole 9 at 48 feet from surface. Still finer grained microlitic porphyritic; very ferruginous amygdaloid. Distance from margin 49.

Grain

Olivine 80x45; 30x27; 38x28; 33x26, av. 1.5x1.05 mm.

Iron oxide growth

Feldspar phenocrysts 28x12; 30x13; 32x16, av. .90x.41 mm.

49-103; (30 feet of drift not counted) (Ss. 15390-7); (53)
corresponds to No. X, 483-508; (Ss. 15540-3). MELAPHYRE, porphyrite; red, finely porphyritic, with an almost felsitic matrix; with chloritic amygdules for the first 15 feet, then a gray trap like the flow above.

Below base of Conglomerate No. (8) (109)
This should be Eagle River bed 46. At this point Marvine found on Eagle River 10 thin, but as he says well defined, beds amounting in all to 147 feet, beds 46 to 55. Just what the correlation may be cannot be determined.

Sp. 15390. Hole 9 at 49 feet from surface. Low angled feldspar.

Grain

Olivine? 4x4; 1.5
Iron oxide 2x2; 2x2; 12x10, av. .16x.14 mm.
Feldspar phenocrysts 37x14; 24x20; 33x12, av. .94x.46 mm.
Augite 5x1; 1x1; 2x0.5; 0.5x1.5, av. .08x.04 mm.

Sp. 15391. Hole 9 at 57 feet from surface. Large amygdules and phenocrysts,—can they be olivine? Also small low angled feldspar; ex. 7°-5°.

Grain

Olivine 48x20; 33x20; 33x22, av. 1.14x.62 mm.
Iron oxide 3; 2; 2
Augite 13x10; 12x10; 9x9, av. .34x.29 mm.

Sp. 15392. Hole 9 at 64 feet from bed rock surface. Feldspar ex. angles, phenocrysts 13°-4°; 9°-14°w3°; 8°-0°; microlites 17°-0°-9°; 13°; 3°; 7°.

Grain

Olivine 4x4; 6x4; 5x4, av. .15x.12 mm.
Iron oxide 4; 6; 6x3; 7x6
Feldspar phenocrysts 15x9; 24x15; 40x12; 43x14, av. 1.01x.41 mm.
Augite 13x5; 13x9; 10x5, av. .36x.19 mm.

Sp. 15393. Hole 9 at 77 feet from surface. Large feldspar very abundant, no sharp distinction between them and the smaller; ex. angles 0°; 10°-12° 0°-9°; 8°-5°; 10°-15°. In this specimen the augite is not so idiomorphic and there begins to be a transition toward the glomeroporphyrite and feldspathic melaphyre type.

Grain

Olivine 3; 3x3; 7x5
Iron oxide 2; 5; 5
Feldspar phenocrysts 28x12; 32x13; 40x12, av. 1.00x.37 mm.
Augite 11x9; 13x9; 15x6, av. .39x.24 mm.

Sp. 15394. Hole 9 at 92 feet from surface. Feldspar ex. angles 0°; in thin microlites; 0°. Distance from lower margin 11.

Grain

Olivine 3x2; 3x2; 2x2, av. .08x.06 mm.
Iron oxide 20x15; 8x8; 10x2, av. .38x.25 mm.
Feldspar phenocrysts 30x23; 45x30; 40x10, av. 1.15x.63 mm.
Augite 2x1; 2x2; 2x1, av. .06x.04 mm.

Sp. 15395. Hole 9 at 100 feet from bed rock surface. Porphyritic microlitic; the low angled feldspar is porphyritic and distinctly corroded; feldspar ex. 10°-1°; 0°-0°; microlitic 25°-23°; 26°-28°; 9°w26°-16°; 29°-30°; 24°-26°w24°-26°. Distance from margin 3.

Grain

Iron oxide 25x17; 19x11; 40x39, ave. .84x.67 mm.
Feldspar phenocrysts 36x14; 76x32; 32x10, ave. 1.02x.56 mm.
Augite 3x3; 5x4; 4x1, ave. .1x.08 mm.

Sp. 15396. Hole 9 at 102 feet from surface. Feldspar phenocrysts ex. 0°; 0°; 0°; 0°-3°; 6°-6°; 0°; 0°; microlites 12°; 0°; 0°; 0°; 0°-8°; 0°; 7°; 0°; 3°; 0°. Distance from margin 1.

Grain

Olivine 23x12; 15x14; 22x18, av. .60x.44 mm.

Iron oxide 2; 3; 2

Feldspar 30x9; 75x16; 53x15, av. 1.58x.40 mm.

Augite 3x1; 2x2; 3x1, av. .08x.04 mm.

Sp. 15397. Hole 9 at 103 feet from surface. Mainly sediment; amygdaloidal porphyritic; microlitic; prehnitic; dark borders to amygdules. Distance from margin 0.

(109)

103-152; (Ss. 15398-402). MELAPHYRE, porphyrite; to the naked eye much like the two flows above, though not so acid; at the top about 20 feet are somewhat amygdaloidal (chloritic) (48) (157)

Sp. 15398. Hole 9 at 113 feet from surface. Considerable altered olivine; little augite; low angled feldspar ex. angles 7°-0°; 0°; 14°-9°w0°; 0°; 0°.

Grain

Olivine 18x13; 22x16; 23x22, av. .59x.51 mm.

Iron oxide 9x5; 9x5; 8x6, av. .26x.16 mm.

Feldspar 23x8; 38x8; 26x8, av. .87x.24 mm.

Augite 30x10; 15x12; 16x6; 17x15, av. .65x.53 mm.

Sp. 15399. Hole 9 at 122 feet from surface. Altered olivine; augite slightly poikilitic not abundant; labradorite extinction angles 33°-37°; 30°-37°; 27°-39°.

Grain

Olivine 20x7; 18x12; 15x13, av. .53x.32 mm.

Iron oxide 8x8; 9x5; 9x1, av. .26x.14 mm.

Feldspar 30x6; 48x23; 48x14, av. 1.26x.43 mm.

Augite 40x30; 18x15; 37x35, av. .95x.80 mm.

Sp. 15400. Hole 9 at 129 feet from surface. Pretty thoroughly decomposed.

Grain

Olivine 15x9; 9x8; 7x6, av. .31x.23

Iron oxide 15x2; 10x4; 14x2, av. .39x.08

Feldspar 22x4; 25x8; 33x4, av. .80x.16.

Sp. 15401. Hole 9 at 144 feet from surface. Little or no augite; olivine abundant; andesite ex. angles 0°-2°w3°-1°; 5°-4°; 20°-8°; 22°w14°-15°.

Grain

Olivine 17x15; 44x18; 23x10, av. .84x.43 mm.

Iron oxide 16x8

Feldspar 43x10; 42x17; 32x10, av. 1.17x.37 mm.

Augite 23x10.

Sp. 15402. Hole 9 at 151 feet from surface. Somewhat amygdaloidal; a little decomposed olivine; porphyritic microlitic; extinction angles 10°-10°. Distance from margin 1.

Grain

Olivine 16x15; 6x6; 6x4, av. .28x.25 mm.

Feldspar phenocrysts 67x17; 31x29; 26x10, av. 1.24x.56 mm.

(157)

152-170; (Ss. 15403-6.) MELAPHYRE, porphyrite; first ten feet red porphyritic amygdaloid. This bed has (at 164 feet) the same (18) (175)

decomposed green, light colored spots, as in No. X at 344 feet.

Sp. 15403. Hole 9 at 154 feet from surface. Amygdules, porphyritic; microlitic; very low angled felspar ex. angles 8°-8° w 6°.

Grain

Olivine 33x24; 12x8; 22x18, av. 67x.50 mm.

Iron oxide 3x1; 9x1; 6x5, av. .18x.07 mm.

Sp. 15404. Hole 9 at 160 feet from surface. All very low angled feldspar, ex. angles 7°-15°-0°; coarser than 15403; many olivine pseudomorphs, but little augite.

Grain

Olivine 29x10; 20x8; 10x7, av. .59x.25 mm.

Iron oxide 3; 4x2; 7x6

Feldspar phenocrysts 38x25; 28x13; 50x15, av. 1.16x.53 mm.

Sp. 15405. Hole 9 at 164 feet from surface. Thoroughly decomposed; same texture but originally more glassy?

Gra n

Olivine 10x10; 20x18; 16x14, av. .46x.42 mm.

Feldspar phenocrysts 32x18; 30x? 22x16.

Sp. 15406. Hole 9 at 170 feet from surface. Microlitic porphyritic; very close to the margin; sharp epidote; very ferruginous; very amygdaloidal.

Gra:n

Olivine 8x5; 7x5; 6x5, av. .21x.15 mm.

Feldspar 11x5; 10x8; 30x11, av. .51x.24 mm.

170-214; (Ss. 15407-8). MELAPHYRE, porphyrite; not very salic (43) (218)

diabasic texture often conspicuous; red and amygdaloidal porphyrite at the margins.

This may well be T 5 b 18 and 19 (flow 12, on p. 256 of report for 1903 and Fig. 37.)

Sp. 15407. Hole 9 at 193 feet from surface. More olivine pseudomorphs than augite; feldspar ex. angles 0°-0°; 12°; 0°-10°; 0°-16°; 17°-10°; 15°-6°; 5°-4°. Distance from margin 23 above, 21 below.

Grain

Olivine 25x15; 20x18; 25x23, av. .70x.56 mm.

Iron oxide 23x1; 11x1; 21x2, av. .55x.04 mm.

Feldspar 34x6; 50x20; 53x10, av. 1.37x.36 mm.

Augite 35x18; 38x18, av. 1.01x.54 mm.

214-222; (Ss. 15408-10). AMYGDALOID; epidote needles, etc., in the half-filled amygdules. (8) (226)

Sp. 15408. Hole 9 at 214 feet from surface. Porphyritic, microlitic, same kind of feldspar as in flows above; 10°-6°; 17°-11°; 0°-4°. Fine grained belts at 214 ft. and 215 ft.,—successive gushes?

Grain

Olivine 12x10; 25x21; 20x18, av. .57x.49

Iron oxide 2; 1; 3

Feldspar 25x11; 30x12; 26x18, av. .81x.41.

Sp. 15409. Hole 9 at 215 feet from surface. Shows flow texture; a much decomposed and altered top of flow?; amygdaloid with green epidote needles.

Grain

Olivine 10x8?; 7x6, av. .28x.23 mm.

Iron oxide 2x0.1; 2x1; 2x1, av. .06x.02 mm.

Feldspar 8x2; 6x1; 17x3, av. .31x.06 mm.

Sp. 15410. Hole 9 at 222 feet from surface. Amygdaloidal fine grained microlitic round amygdules; very much decomposed. Margin here at 222.

Grain

Olivine 10x7; 7x7; 6x5, av. .23x.19 mm.

Iron oxide 3x2; 4x3; 5x4, av. .12x.09 mm.

Feldspar phenocrysts 27x6; 20x7; microlites 10x1, av. .57x.14 mm.

Sp. 15411. Hole 9 at 228 feet from surface. Microlitic porphyritic, amygdaloidal; low angled feldspar; iron oxide pseudomorph, after olivine?

Grain

Olivine 32x20; 5; 27x20

Iron oxide 8x6; 11x7; 7x6, av. .26x.19

Feldspar phenocrysts 32x10; 60x35; 30x11, av. 1.22x.56.

222-235; (Ss. 15411-2) AMYGDALOID. Seam or separation line of fine grained SEDIMENT. at base (13) (239)

Compare the covered belt above belt 58 on Eagle River and also the sandstone seam, belt 63.

Sp. 15412. Hole 9 at 235 feet from surface. Fine grained sediment. Compare Eagle River No. 63 and T. 5 b 20.

235-279; (Ss. 15413-6). MELAPHYRE; more or less amygdaloidal, with laumontite and datolite. (44) (283)

Compare T. 5 flow No. 7 and Eagle River 60-62 (Fig. 37).

Sp. 15413. Hole 9 at 246 feet from surface. Much altered olivine; poikilitic augite scarce; feldspar ex. 7°-2°w4°; 4°-2°.

Grain

Olivine 36x22; 30x26; 20x17, av. .86x.65 mm.

Iron oxide 34x3; 9x5; 8x2, av. .51x.10 mm.

Feldspar 32x8; 25x8; 51x5, av. 1.08x.21 mm.

Augite 75x45; 55x50; 84x40; 70x70, av. 2.37x1.70 mm.

Sp. 15414. Hole 9 at 259 feet from surface. Much decomposed, with seam that appears to contain sediment.

Grain

Olivine 30x20; 17x15; 20x20, av. .67x.55 mm.

Iron oxide 8x6; 21x2, av. .28x.13 mm.

Feldspar 45x10; 10x4.

Sp. 15415. Hole 9 at 275 feet from surface. Poikilitic augite; much decomposed olivine; high angled feldspar ex. 10°-23°w32°-41°; 32°-23°; 11°-20°w34°; 16°-24°w-34°.

Grain

Olivine 45x25; 15x10; 43x23, av. 1.03x.58 mm.

Iron oxide 8x5; 25x5; 14x2, av. .47x.12 mm.

Feldspar 17x5; 28x9; 25x15, av. .70x.29 mm.

Augite 35x30; 40x33; 53x40, av. 1.28x1.03 mm.

Sp. 15416. Hole 9 at 279 feet from surface. Decomposed olivine; no augite visible; low angled feldspar ex 7°; 0°; 0°; 0°; -0°; 7°-4°; 5°-1°.

Grain

Olivine 15x14; 9x8; 24x12, av. .48x.34 mm.

Iron oxide 3; 5x4; 15x2, av. .13 mm.

Feldspar 20x6; 32x14; 53x6, av. 1.05x.26 mm.

Sp. 15429. Hole 9 at 309 feet from surface. Feldspar extinctions 0°; 14°; 0°-10°; 8°; 0°; 0°; 0°. Distance from margin 4 ft.

Grain

Olivine 2; 2; 5x3, av. .08 mm.

Feldspar 8x0.2; 7x0.5; 8x1, av. .23x.01 mm.

Augite 8x7; 5x4; 9x4; 13x7, av. .29x.19 mm.

279-291; (Ss. 15417-24). Ash bed and scoriaceous CONGLOMERATE, (12) (295) The top of this bed is a very fine grained genuine ash, under which for a foot or more it is like a dark red sandstone. Lower we encounter a lot of laumontitic amygdaloid, and some samples which show more clearly its characters as a volcanic breccia, with intermingled sediment and scoria. It is much decomposed. Marvine's bed No. 63? Dips on drill cores 25°, 23°, with signs of cross-bedding.

Sp. 15417. Hole 9 at 279 feet from surface. Contact of microlitic porphyrite with ashbed; 10°-6°; 0°; 0°; 0°; 0°; microlites are 5x0.1 etc. Distance from margin 0.

Grain

Olivine 8x5; 4x4; 6x5, av. .18x.14 mm.
Iron oxide dust
Feldspar 13x12; 12x8; 17x7, av. .42x.27 mm.

Figure 1 of Plate VI of the Isle Royale report is a photograph of part of this bed. It is of interest as showing unquestioned ash, in view of the fact that Irving had doubted the existence of genuine ash. At the very top of the photograph the contact with the overlying trap is shown. A little below the center is a rather large grain which is very vesicular.

Sp. 15418. Hole 9 at 279 feet from surface. Ashbed.

Sp. 15419. Hole 9 at 280 feet from surface. Ashbed.

Sp. 15420. Hole 9 at 281 feet from surface. Fine grained microlitic amygdaloid; feldspar extinctions 2°; 0°; 8°; 3°; 0°; 0°; 0°-11°; 11°-7°; 6°; 2°; 0°.

Grain

Feldspar 6x1; 8x1; 7x0.5, av. 0.21x0.02.

Sp. 15422. Hole 9 at 285 feet from surface. Very fine grained amygdaloid; sediment in one corner.

Sp. 15423. Hole 9 at 287 feet from surface. Fine grained amygdaloid; one large brotocrystal, i. e., corroded; extinction angles 7°- -18°; 6°; 0°; 7°-12°; 0°.

Grain

Feldspar phenocrysts 32x17; 6x12, av. .63x.48.

Sp. 15424. Hole 9 at 290 feet from surface. Coarser grained phenocrysts; much of the older and larger feldspar is andesite; 5; 15°-11°w6°-2°; 6°-3°; 3°-11°; 7°-0°. Margin is at 291 feet.

291-313; (Ss. 15425-9). AMYGDALOID. Some of the specimens (21) look like ophites. They are all much decomposed, and it is (316) barely possible that they may all be part of the bed of scoriaceous conglomerate which occurs above and below.

Sp. 15425. Hole 9 at 291 feet from surface. Fine grained microlitic porphyrite and sediment; no phenocrysts; feldspar ex. 25°; 33°-26°; 30°-26°; 21°; 36°; 28°-31°. Distance from margin 0. Augite granular ? very fine.

Sp. 15426. Hole 9 at 291 feet from surface. Fine grained microlitic; granules of augite or olivine; feldspar ex. 15°; 26°; 15°-26°; 0°.

Grain

Olivine 2; 2; 3x2; 4x4, av. .08 mm.
Feldspar 3x.2; 4x0.2, av. .11x.006 mm.
Augite granular?

Sp. 15427. Hole 9 at 294 feet from surface. Very fine grained, small microlites; altered olivine; feldspar extinctions 0°; 0°; 28°-26°; 19°-18°.

Grain

Olivine 2x1; 2x2; 2x2, av. .06x.05 mm.
Feldspar 4x0.3; 3x0.2; 8x1.0, av. .15x.005 mm.

Sp. 15428. Hole 9 at 296 feet from surface. The augite is *extra coarse* along one amygdaloidal vein; decomposed.

Grain

Olivine 3x3; 3x2; 5x5; 10x3, av. .17x.10 mm.

Feldspar 12x1; 15x3 extra; 15x2, av. .42x.06 mm.

Augite 84x40; 80x38; 30x30, av. 1.94x1.08 mm.

9.313-328; (Ss. 15430-6). CONGLOMERATE, scoriaceous. This (15) (331) contains green decomposed ash, and a calcareous cement. The three beds just described bear a striking analogy, in lithological character and stratigraphic position to Marvine's beds No. 63 to No. 65, the "Ashbed" *par excellence*.

One of the conglomerates would be No. 17 of Marvine's plate, i. e., the Hancock West conglomerate. There is, however, a fault in the Eagle River series at this point, and I think that No. 64 and No 65 are really the same bed. Marvine applies one and the same number to cover both the Ashbed and the underlying melaphyre. The relative position to the beds already correlated is as it should be. The only question is as to the relation of this and the beds just above. This horizon may be recognized in the Arcadian section (Fig. 41) and the Winona (Fig. 50) as well as near Portage Lake as described by Marvine.

Sp. 15430. Hole 9 at 313 feet from surface. Very amygdaloidal; mass of fragments charged with calcite and characteristically filled with a large number of very small amygdules; 13°-1°; 0°; 0°; 0°; 0°; 0°; 9°-16°; 0°; 0°; 14° feldspar ex.

Grain

Feldspar 2x1; 8x2; 2x5, av. .12x.08.

Sp. 15431. Hole 9 at 315 feet from surface. Very calcareous; fragments of similar microlitic porphyrite; feldspar extinction angles 0°; 0°; 13°-2°.

Grain

Feldspar 3x.1; 3x.2, av. .10x.005 mm.

Sp. 15431 a. In this section comes a glomeroporphyrite. The fragments in the bed above are *not* glomeroporphyritic; sediment with microlitic fragments.

Sp. 15432. Hole 9 at 316 feet from surface. Ash bed of microlitic porphyry; feldspar extinctions 10°; 0°; 13°-0°; 0°; 11°-7°; very fine grained.

Grain

Olivine 15x13;

Feldspar 2.5x0.2.

Sp. 15433. Hole 9 at 317 feet from surface. Glassy porphyritic amygdaloid; feldspar extinction angles 17°-15°w6°-6°; 7°-7°; 18°-12°; 0°. The driller reported rock like No. 15430 to continue down to 329 feet where we have rock like 15428.

Grain

Olivine 17x17; 12x8; 10x8, av. .39x.33 mm.

Feldspar phenocryst 37x6; microlite 6x3; 12x3, av. .55x.12 mm.

Sp. 15434. Hole 9 at 319 feet from surface. Amygdaloid mixed with sediment; decomposed porphyritic with prehnite; very fine grained.

Sp. 15435. Hole 9 at 321 feet from surface. Secondary poikilitic epidotic amygdaloid; microlitic. The epidote is in very pretty sharp crystals.

Sp. 15436. Hole 9 at 323 feet from surface. Fragments of microlitic amygdaloid; irregular with fragmental cement; may be replacement. Margin at 328.

Grain

Iron oxide granules, very abundant

Feld-par 26x10; 40x25; 15x1; 10x1, av. .75x.30 mm.

FIRST BED OF MARVINE'S SERIES A.

328-385; (Ss. 15437-41). MELAPHYRE, porphyrite (THE ASHBED); like the porphyrite above 485 feet in No. X, already described, I think it is the same bed as the one at the top of No. VIII down to 47 feet. We pass then at this point from the record of No. IX to that of No. VIII. But there is a peculiarity about the rest of the record of No. IX that deserves mention. After some feet of amygdaloids and clayey seams with some *copper* at 413 feet, No. IX finishes below 427 feet in a large bed of ophite, the like to which we do not find in No. VIII until we get down to 196 feet. Either, therefore, one of these two correlations (that of 385 feet in No. IX to 47 feet in No. VIII or that of 427 feet in No. IX to 196 feet in No. VIII) must be given up, or we must suppose a remarkable wedging out of intermediate beds, or lastly we must suppose that a fault has cut out part of the record of No. IX. But the correlations are—microscopic evidence and all else considered—very good. Moreover, in the interval, drill hole No. IX showed marked signs of disturbance, especially between No. IX, 385 feet, and No. IX, 427 feet. At 408 feet there is some kind of a break with much decomposed and prehnitic rock; at 413 feet there is a seam with *copper;* at 420 feet a datolite vein; at 430 feet a brecciated amygdaloid. Therefore the last supposition seems most probable—that there is a fault. The character of a fault like the one here supposed depends upon whether the upper or the lower correlation gives the normal dip. If we assume as undisturbed the correlation 385 feet in No. IX, with 47 feet in No. VIII, and add to the difference (338 feet) the excess of elevation of No. VIII over No. IX (376.3-202.5 the altitude of the rock at No. IX; the surface of the ground is 30 feet higher) 174 feet, and divide by the distance between the holes along the section (2,218 feet) we shall have 0.231, i. e., tan 13°, about half a degree steeper than the dips we have computed thus far in our section south of this point, but the same as dips computed at points further north. On the other hand the deeper of the two correlations, 427 feet in No. IX with 196 feet in No. VIII, would give us 0.183=tan 10° 20′. This is much flatter than anything we have reason to expect, and the inference is that the fault affects this correlation rather than the other. Thus we are led to the conclusion that if there is a fault it cuts No. IX, raising the lower part of it but not the upper. Hence it is a normal fault with northerly or westerly hade. Fig. 8 of the Isle Royale Report may represent it. (56) (56)

According to our correlation, the distance from the bottom of the bed corresponding to Marvine's No. 43, to the bottom of this bed corresponding to his No. 65, is (1202-806) (or 331+56+11) 396 feet, while the corresponding distance in the Eagle River section is 573 feet—thicker in about the usual ratio, i. e., about 3:2. The running distances above are from the base of (44). This is the melaphyre part of Marvine's bed 65 of the Eagle River section of which an analysis has recently been made, Table XII, No. 1.

Prof. A. N. Winchell permitted me to examine a section of the specimen analyzed. My notes follow:

Coll. 607. Section 4607 U. of Wis. See Journal of Geol., 1908, p. 772 analysis. Is too thick. Augite color up to .000948÷.029=.033 mm.+. Ashbed diabase. Bed 65 Eagle River section, sample No. 7 of Rohns collection.

Augite is in granules generally, here and there in patches beginning to be "poikilophitic." The granules are .10 to .05 mm. in size and smaller. A few large pieces apparently left from an early coarser crystallization run up to .2-3 mm.

Feldspar is quite varied in size, glomeroporphyritic, largest aggregate is 3.5 mm. x 2; composed of laths each about 1.2x0.3, 4-7.3=2 (5.6) E=338 and 64.18. Albite twin parallel M (010) ex. 25.5°—21.5° and Karlsbad twin ex. 14.2°-16.5°. Bire-

fringence highest for Karlsbad 16.5°, others slightly lower. The largest grain is $Ab_{75}\ An_{25}$. The small feldspar laths probably nearly at r. a. to P. and to M are ab. .15x.03 mm. Ex. 4°, 3°-6°, 4°-5°, 0, 1, 3. ave. 3° which, supposing them perpendicular to P and M. indicate $Ab_3\ An_1$, between that and $Ab_5\ An_3$. Olivine pseudomorphs into green serpentine and red iron oxides are generally irregular and not very common. 0.5 mm. is the largest. They are probably corroded remnants.

Iron oxides magnetite are in triangular octahedral sections up to about .35 mm. It is quite abundant original. There is some secondary.

Green substances replace olivine and feldspar phenocrysts and possibly fill miarolitic interstices.

This is an (oligoclase) melaphyre porphyrite of the ashbed type. As A. N. W. says it is related to Irving's bed 87. Compare 15515 (a) of Volume VI, Pl. V. Sp. 15438 is figured in Pl. VI, Fig. 4, p. 67, which is as I made it, the equivalent flow on Isle Royale. It is a lucky coincidence that I figured just this flow. See also pp. 159, 167, 170. This is probably near the center of the flow, at any rate quite augitic and not near the top.

Sp. 15437. Hole 9 at 329 feet from surface. Porphyritic microlitic amygdaloid; sharp difference between porphyritic and ground feldspars; low angled feldspars; extinction angles 20°-10° phenocrysts 26°-10°w10°-1°; 23°; 9°-0°; 10°-0°; 13°-6°; microlites 0°; 0°; 0°-15°; 0°-20°; 0°; 10°-4°.

Grain

Feldspar phenocrysts 33x30; 33x23; 55x7, av. 1.21x.60; microlites 5x1; 5x0.2; 8x1, av. .18x.02.

Sp. 15438. Hole 9 at 348 feet from surface. Glomeroporphyritic low angled feldspar; 0°; 0°; 0°; porphyritic feldspar 7°-6°.

Grain

Olivine 5x4

Feldspar ground mass 7x2; 12x2; 17x2, av. .36x.06 mm.

Augite 3x1.5; 5x4; 4x4; 4x3, av. .12x.10 mm.

The structure is illustrated by Fig. 4 of Plate VI, the variation in grain by the points marked (a) in Fig. 19 of the Isle Royale report. The specimen from Bed 65 of the Eagle River section 4607 University of Wisconsin is similar to this section.

Sp. 15439. Hole 9 at 360 feet from surface. Phenocryst extinction angles 33°-24°; microlites 0°w13°-23°; 25°-20°; 17°-21°.

Grain

Feldspar ground mass 8x1; 8x2; 8x1, av. .24x.04 mm.

Augite 2x1; 2x1; 3x2, av. .07x.04 mm.

Sp. 15440. Hole 9 at 383 feet from surface. Extinctions near 0°.

Grain

Olivine 20x20; 24x19; 19x18, av. .63x.57 mm; younger olivine 2; 2; 5?

Feldspar phenocrysts 24x8; microlites 4x1; 3; 4x1

Augite 0.5x0.5; 1x1; 1.5x1.5, av. .02x.03 mm.

Sp. 15441. Hole 9 at 385 feet from surface. Similar low angled feldspar in three generations or sizes; extinction angles 11°x9°; 0°; 0°; phenocrysts 12°w5°-4°.

Grain

Olivine 25x14; 5

Iron oxide 17x10; 8x6, av. .41x.26 mm.

Feldspar phenocrysts 30x4; 43x11; 25x24; 58x14, av. 1.30x.44 mm.

Augite 1; 1.5; 3x1?

Sp. 15442. Hole 9 at 385 and 386 feet from surface. Microlitic porphyritic amygdaloid; occasional large olivine; phenocrysts 7-5; 18-16; 15-5; 6; 12-0.

Grain

Olivine 18x10; 18x14; 24x30, av. .60x.54 mm.

Feldspar phenocrysts as before; ground mass 7x1; 12x1; 11x1, av. .30x.03 mm.

Sp. 15443. Hole 9 at 388 feet from surface. Coarser.

Grain

Iron oxide 3x5; 4x2; 5x.2, av. .12x.07 mm.

Feldspar phenocrysts 32x17; 34x8, av. 1.11x.41 mm.

Augite 10x5; 7x5; 13x10; 14x11; 8x6, av. .34x.35 mm.

Sp. 15444. Hole 9 at 400 feet from surface. Coarser yet low angled feldspar, the larger ones becoming prevalent; very big.

Grain

Augite 15x13; 23x25; 23x19, av. .61x.57 mm.

Sp. 15445. Hole 9 at 408 feet from surface. Poikilitic augite; much low angled feldspar; part microlitic feldspar; extinction angles 0; 0; 0; 7°; 10°; 0; 5°.

Grain

Olivine 2; 4x2; 3; 44x36

Iron oxide 7x.7; 4; 2

Feldspar 10x2; 8x2; 13x5, av. .31x.09 mm.

Augite 16x12; 30x22; 18x11, av. .64x.45 mm.

Sp. 15446. Hole 9 at 408 feet from surface. Fine grained microlitic contact with sediment and ash fragments; prehnitic.

Grain

Feldspar microlites 5x.2; 5x.1; 10x2?, av. .20x.02 mm.

Sp. 15447. Hole 9 at 411 feet from surface. Abundant glomeroporphyritic low angled feldspar; altered olivine; small augite?

Grain

Olivine 4x4; 6x5; 15x9, av. .25x.18 mm.

Feldspar 8x1; 5x1; 11x1, av. .24x.03 mm.

Augite 7x1; 8x5; 12x10, av. .27x.16 mm.

Sp. 15448. Hole 9 at 413 feet from surface. Amygdaloid of some zeolite (+2V small R > V, good cleavage, moderate refringence, ex. generally—especially for the sections with stronger birefringence. Cf. pectolite) glassy contact with sediment.

Grain

Olivine 6x6; 7x7; 5x5, av. .18x.18

Feldspar 16x5; 16x4; 12x4, av. .44x.13

Augite dust.

Sp. 15449. Hole 9 at 418 feet from surface. Porphyritic, microlitic amygdaloid with chloritic amygdaloid and altered olivine; small amygdules.

Grain

Olivine 15x13; 20x12; 19x13, av. .54x.38 mm.

Feldspar phenocrysts 30x9; 39x37, av. 1.15x.76 mm.; microlites 6x.1; 3x.1; 5x.1, av. .14x.003.

Sp. 15450. Hole 9 at 420 feet from surface. Glomeroporphyritic; coarser long laths in ground; olivine altered to micaceous bowlingite? extinction angles 5-7; 18-8-1w5-26.

Grain

Olivine 4; 7x6; 9x7

Feldspar phenocrysts 30x25; 20x7; 34x10; 38x32, av. 1.16x.61 mm.

Augite dust up to 1?

Sp. 15451. Hole 9 at 421 feet from surface. Sediment mainly; rarely prehnitic granules; 2x3; 4x3; 15x15, av. .21x.21 mm.

Sp. 15452. Hole 9 at 423 feet from surface. Olivine very sharp; much porphyritic, microlitic; much altered olivine; feldspar extinction angles 6°-4°; 0; 0; 0.

Grain

Olivine 12x5; 10x3; 22x13, av. .44x.21 mm.

Feldspar 25x15; 43x15, av. 1.10x.50 mm.

Sp. 15453. Hole 9 at 427 feet from surface. Very complex interlocking combination of sediment and marginal microlitic porphyrite.

Grain

Feldspar phenocrysts 25x10; 13x1; 12x1; 9x1; 8x.1; 24x2, av. .50x.02

Augite none.

Sp. 15454. Hole 9 at 430 feet from surface. Slightly coarser amygdaloids with sediment in some amygdules; very prehnitic; feldspar decomposed.

Grain

Olivine 6; 20x5; 7x5

Feldspar 18x4; 22x3, av. .66x.11

Augite 15x11; 20x10, av. .58x.35.

Sp. 15455. Hole 9 at 433 feet from surface. Little poikilitic augite; low angled feldspar; altered olivine; ilmenite?

Grain

Olivine 35x17; 9x9; 27x25, av. .71x.51 mm.

Iron oxide thin laths

Feldspar 50x6; 45x15; 43x10, av. 1.38x.31mm.

Augite 50x35; 70x45; 46x18, av. 1.66x.98 mm.

Sp. 15456. Hole 9 at 446 feet from surface. Similar to 15457.

Grain

Olivine 30x14; 23x22; 33x25, av. .86x.61 mm.

Feldspar 30x5; 33x9; 48x15, av. 1.11x.29 mm.

Augite 35x35; 78x45; 52x40, av. 1.65x1.20 mm.

Sp. 15457. Hole 9 at 452 feet from surface. Similar to 15455 but distinctly coarser; large altered olivine; feldspar extinction angles 6-8°; 12-°11°w18°-2°; 6°-4°w14°-8°; 16-6°.

Grain

Olivine 30x25; 25x20; 48x23, av. 1.03x.68 mm.

Feldspar 42x17; 40x9; 55x18, av. 1.37x.44 mm.

Augite 130x55; 80x80; 80x66, av. 2.90x2.01 mm.

Sp. 15458. Hole 9 at 456 feet from surface. Much decomposed large poikilitic patches of augite, feldspar all corroded.

Grain

Olivine 28x20

Iron oxide 12x1; 9x1, av. .25x.03 mm.

Augite 100x70; 120x70; 90x65, av. 3.10x2.05 mm.

Sp. 15459. Hole 9 at 462 feet from surface. Poikilitic and a trace of more idiomorphic augite and more basic feldspar than above; extinction angles 35°-27°-w19°-14°; 11°-11°w41°; 12°-15°; 10°-20°.

Grain

Olivine 30x15; 45x30; 35x18, av. 1.10x.63 mm.

Feldspar 53x11; 30x7; 42x12; 25x4, av. 1.25x.28 mm.

Augite 190x80; 115x95; 125x120, av. 4.30x2.95 mm.

Sp. 15460. Hole 9 at 467 feet from surface. Much decomposed; augite all gone; low angled feldspar extinction angles 9°-14°-26°; 8°; 0; 14°.

Grain

Olivine 18x13

Iron oxide 22x1; 7x6; 15x15, av. .44x.22 mm.

Feldspar 40x9; 44x7; 53x12, av. 1.37x.28 mm.

Sp. 15461. Hole 9 at 468 feet from surface. Very coarse poikilitic augite; large decomposed olivine grains; extinction angles 19°-19°; 29°-35°w14°-11°; this is probably halfway down in the flow as it is getting basic but as it is very coarse, there must be at least 30 feet more.

Grain

Olivine 17x15; 20x20; 22x10, av. .59x.45 mm.

Feldspar 30x10; 43x17; 34x8, av. 1.07x.35 mm.

Augite 250x160; 80x80?; 80x80?, av. 4.10x3.20 mm.

Sp. 15328. Hole 8 at 2 feet from surface. Porphyritic; decomposed olivine; idiomorphic augite granules; mainly low angled feldspar like 15439 (ex. 31°-14°; 0°; 0°-22°; 20°-9°), but in one place a basic addition (46°-31°).

Grain

Olivine 15x12; 20x10

Feldspar microlites 7x1; 10x2; 8x6, av. .25x.09 mm.

Augite 4x2; 3x1; 2x1, av. .09x.04 mm.

Sp. 15329. Hole 8 at 27 feet from surface. Feldspar ex. angles 31°-14°; 0; 0-20°; 10°-2°; 0; 46°-31°; basic addition; similar to 15328.

Grain

Olivine 10x7; 9x7, av. .31x.23 mm.

Iron oxide 12x11; 14x10; 8x6, av. .34x.27 mm.

Feldspar, phenocrysts 39x10; a glomeroporphyritic group 80x75; microlites 5x1; 12x2; 10x2, av. .27x.05 mm.

Augite 2x1; 3x1; 3x2, av. .08x.04.

Sp. 15330. Hole 8 at 29 feet from surface. Similar to 15329; feldspar ex. angles 0°-16°; 3°w27°-22°; 25°; 10°w31°-27°; 33°-33° nearly; 18°-18°w18°-18°; changing into a more basic feldspar? with ex. 17°-17° and 40°-25°.

Grain

Olivine 5x4; 4x3; 19x17, av .28x.24 mm.

Iron oxide 4x2; 7x5; 8x4, av. .19x.11 mm.

Feldspar phenocrysts 43x19; 35x8; 47x12, av. 1.25x.39 mm.

Augite 4x2; 2x2; 4x1, av. .10x.05 mm.

Sp. 15331. Hole 8 at 37½ feet from surface. Similar to 15329; feldspar extinction angles 8°-15°; 20°-8°; 7°-6°; 10°-1°.

Grain

Olivine 10x8; 16x13; 10x9, av. .36x.30 mm.

Iron oxide 9x1; 6x1; 7x5; 8x7, av. .25x.11 mm.

Feldspar phenocryst 30x10; microlites 6x1; 5; 9x0.5

Augite 3x2; 5x3; 2x2, av. .10x.07 mm.

Sp. 15332. Hole 8 at 38 feet from surface. Similar to 15329; the two kinds of chlorite.

Grain

Olivine 30x23; 22x15; 10x7, av. .62x.45 mm.

Iron oxide 10x6

Feldspar phenocrysts 30x9; 46x10; 42x17, av. 1.18x.36 mm.; microlites 5x1, 6x1, av. .18x.03 mm.

Augite 2x1; 2x1; 2x2, av. .06x.04 mm.

Sp. 15333. Hole 8 at 45 feet from surface. Feldspar ex. angles 0; 0; 0; 10°-5°.

Grain

Olivine none?

Iron oxide 5x5; 21x10; 10x8, av. .36x.23 mm.

Feldspar phenocryst 36x15; microlites 8x1; 7x1; 4x1, av. .19x.03 mm.

Augite 1x1; 1x1; 2x1, av. .04x.03 mm.

Sp. 15334. Hole 8 at 47 feet from surface. Abundant porphyritic microlitic; low angled feldspar in skeleton forms with breadth only a fraction of a thirtieth of a mm. These skeleton forms are those mentioned by Tammann in case of considerable undercooling D below that of maximum velocity of crystallization. Feldspar ex. angles 5°-0°; 14°-10°; 27°-6°; 0°; 0°.

Grain

Olivine 7x5; 8x5; 17x12, av. .32x.22

Iron oxide dust

Feldspar phenocrysts 15x5; 20x11; microlites 3x0.1, av. .58x.26

Augite dust.

The grain of the above sections is plotted in the points marked b of Fig. 19 of the Isle Royale Report.

(56)

8.47-71; (Ss. 15335-7). Feldspathic MELAPHYRE; the top 13 feet (22) (78) amygdaloidal; intermediate type between ophite and porphyrite, not markedly belonging to any subdivision of the melaphyre; like the flows just below. It is correlated with and just about the size of No. IX, 385-418. (Ss. 15442-15448).

Sp. 15335. Hole 8 at 51 feet from surface. Poikilitic augite, patchy; feldspars (seriate) run gradually down and it looks as though the magma came to rest only toward the end of feldspar formation; ex. 7°-14°-4°; 10°-6°w20°; 21°-18°.

Grain

Olivine 8x6; 15x7; 20x19, av. .43x.32 mm.

Iron oxide with olivine

Feldspar (larger) 45x17; 30x10; 23x10, av. .98x.37 mm.

Augite 17x15; 12x12; 16x14, av. .45x.41 mm.

Sp. 15336. Hole 8 at 63 feet from surface. Feldspar much decomposed; remnants do not appear high angled.

Grain

Olivine 3x3; 5x4; 7x5, av. .15x.12 mm.

Iron oxide 21x12; 5x5; 5x5, av. .31x.32 mm.

Feldspar 30x13; 18x8; 31x8, av. .79x.29 mm.

Augite 25x20; 35x25; 23x15, av. .83x.60 mm.

Sp. 15337. Hole 8 at 71 feet from surface. Microlitic porphyritic; hardly any augite is visible; extinction of phenocrysts 13°-12°w4°-5°.

Grain

Olivine 14x9; 10x8; 14x12, av. .38x.29

Iron oxide dust

Feldspar 44x27; to 10x1 in a pretty continuous series from phenocryst to microlite.

These sections do not match very well those of Hole 9 at 385-408, for though the feldspar and the thickness is similar, that has much more augite. The fault mentioned in No. 9 may account for it.

71-89; (Ss. 15338-9). MELAPHYRE, fine grained and amygdaloidal. (18) (96)

In No. IX the records are much mixed along here. There are slide or flow contacts at 408 feet, 413 feet, 421 feet, with fine grained, red, chloritic, datolitic and prehnitic amygdaloids. Here is where I have supposed that a fault goes through No. IX.

Sp. 15338. Hole 8 at 75 feet from surface. Plagioclase ex. 6°-4°; 6°-5° and similar in other half of a Karlsbad twin.

Grain

Iron oxide 8x0.6; 8x0.4; 8x2, av. .24x.12 mm.
Feldspar 18x7; 20x19; 46x17, av. .84x.43 mm.
Augite 22x13; 23x17; 20x10, av. .65x.40 mm.

Sp. 15339. Hole 8 at 89 feet from surface. Much microlitic decomposed amygdaloid mixed with sediments.. Close to margin.

Grain

Olivine 10x6
Iron oxide secondary dust
Feldspar microlites 16x2; 11x2; 11x1.5, av. .38x.05 mm.

89-103; (Ss. 15340-1). MELAPHYRE, amygdaloidal. (14) (110)

Sp. 15340. Hole 8 at 96 feet from surface.

Grain

Olivine 46x40; 40x20; 32x20, av. 1.18x.80 mm.
Iron oxide 8x8; 7x6; 20x3, av. .35x.17 mm.
Feldspar 23x7; 41x15; 31x9, av. .95x.31 mm.
Augite 30x20; 30x28; 34x29, av. .94x.77 mm.

Sp. 15341. Hole 8 at 103 feet from surface. Phenocrysts very numerous; seriate, i. e., no sharp line in size; ex. 3°-11°w15°-18°; 20°-18°w4°-4°.

Grain

Olivine 5x4; 4; 3; 11x5
Iron oxide 15x1; 5x2, av. .33x.05 mm.
Feldspar phenocrysts 22x13; 33x18; 25x10; 43x25, av. 1.02x.55 mm.
Augite 5x5; 4x3; 15x12, av. .24x.20 mm.

103-135; (Ss. 15342-4). MELAPHYRE, amygdaloidal (31) (141)

Sp. 15342. Hole 8 at 111 feet from surface. Much decomposed.

Grain

Olivine 20x12; 22x17, av. .70x.48 mm.
Iron oxide associated with olivine
Feldspar 27x5; 24x5, av. .85x.41 mm.
Augite 45x15; 30x30; 215x60, av. 2.90x1.05 mm.

Sp. 15344. Hole 8 at 135 feet from surface. Feldspar extinctions 8°-4°w8°; 17°-10°; 12°w5°-5°.

Grain

Olivine 20x11; 10x9; 8x6; 10x9, av. .40x.27 mm.
Iron oxide 4x4; 7x7; 6x5, av. .17x.16 mm.
Feldspar 20x7; 14x5; 36x5, av. .70x.17 mm.
Augite 10x9; 15x6; 17x15, av. .42x.30 mm.

135-146; (Ss. 15345-7). MELAPHYRE, amygdaloidal 11 (152)

Sp. 15345. Hole 8 at 135 feet from surface. Porphyritic feldspar has low angles: microlites of ground mass also; there are chlorite and prehnite amygdules.

Grain

Olivine 20x15; 11x6; 13x11, av. .44x.32 mm.
Iron oxide 4x0.6 in secondary dust
Feldspar phenocrysts 24x20; 24x8; 26x9, av. .74x.37 mm.; microlites 10x2; 9x0.6; 10x1, av. .29x.03 mm.
Augite 8x8; 3x3; 10x10.

Sp. 15346. Hole 8 at 140 feet from surface. Big altered olivine; large low angled feldspar; a little fibrous augite.

Grain

Olivine 20x13; 28x18; 26x22, av. .74x.53 mm.

Iron oxide in dust and with olivine pseudomorphs.

Feldspar 30x17; 26x1.5; 35x8, av. .91x.26 mm.

Augite 10x4; 10x2; 8x1, av. .28x.07 mm.

Sp. 15347. Hole 8 at 146 feet from surface. Very little augite; low angled seriate feldspar ex. 0; 0; 0; 0; 8°-11°; amygdaloid. At margin.

Grain

Olivine 7x7; 12x10; 9x7, av. .28x.24 mm.

Eeldspar 15x2; 12x7; 13x8, av. .40x.17 mm.

Augite 2x1; 1x1; 1.5x1.5, av. .04x.03 mm.

146-164; (Ss. 15348-9). MELAPHYRE, amygdaloidal. (18) (170)

Sp. 15348. Hole 8 at 146 feet from surface. Very fine grained microlitic amygdaloid; ex. 0°; 14°; 4°; 8°; 6°-8°; 8°-11°; 8°-7°.

Grain

Olivine 20x5; 12x5; 15x12, av. .47x.22

Feldspar phenocrysts 10x3 to 2x0.1; 3;.4

Augite none.

Sp. 15349. Hole 8 at 151 feet from surface. Long, patchy half idiomorphic augite; low angled feldspar; ex. 4°-2°-15°; 0°; 15°-10°; 7°-9°; 0°; 8°; 10°; small altered olivines as usual. Margin at 164.

Grain

Olivine 18x13; 24x19; 10x8, av. .52x.40 mm.

Iron oxide around the altered olivine

Feldspar 21x9; 34x14; 32x7, av. .87x.30 mm.

Augite 7x7; 31x13; 40x10, av. .78x.30 mm.

164-196. Ss. 15350-3. MELAPHYRE, amygdaloidal, perhaps (31) (201)

largely pseudamygdules, of laumontite, chlorite and prehnite.

The flows above are all of moderate size and, though varying somewhat, have the general habit of the less augitic melaphyres, i. e., the melaphyre porphyrites. The microscope shows that they carry oligoclase feldspar. Compare T. 5 b 18-20.

Sp. 15350. Hole 8 at 164 feet from surface. Altered glass very scoriaceous; microlitic; the phenocrysts run out into fibres; 0°-0°-8°; 0°-7°-12°.

Grain

Olivine 13x12

Feldspar 22x12 down to tufted microlites.

Sp. 15351. Hole 8 at 167 feet from surface. Large altered olivine is much corroded; a microlitic amygdaloid very fine grained around amygdules; feldspar extinction 7°-8°w4°.

Grain

Olivine 2; 7x5; 16x14

Feldspar 14x8; 20x12; 20x2, av. .54x.22.

Sp. 15352. Hole 8 at 180 feet from surface. Decomposed coarser but little augite left, laumontite!

Grain

Olivine 17x14; 13x13; 34x32, av. .74x.59 mm.

Iron oxide with olivine

Feldspar replaced by laumontite

Augite 32x20; 25x20, av. .95x.66 mm.

Sp. 15353. Hole 8 at 196 feet from surface. Very fine grained; microlitic amygdaloid; laumontite and chlorite in amygdules and prehnite. Margin.

Grain

Olivine 5x2; 7x7; 4x3, av. .16x.12 mm.
Iron oxide 10x1; 9x1; dust
Feldspar 12x2; 13x3, av. .41x.08 mm.

(201)
8.195-273; (Ss. 15354-8). MELAPHYRE, ophite. This bed (75) (276)

for 3 feet is very amygdaloidal, then coarser, with occasional chloritic amygdules, and becoming still coarser it shows the rusty specks of micaceous altered olivine; toward the base it is fine grained with datolite veins. This matches very closely No. IX, 427-468+, which is so coarse when the hole ends that the latter evidently stops in the middle of the flow. This, which is a well marked ophite, the fourth bed above a sandstone at 369 feet, should correspond to some bed in the Tamarack shaft 5 below flow 12, probably flow 13, T 3 b 9, which is a fresh black ophite quite different from the porphyrites above. Compare also Eagle River bed 72.

Sp. 15354. Hole 8 at 223 feet from surface. Poikilitic augite; not abundant (large olivine pseudomorph?) low angled feldspar.

Grain

Olivine 35x20; 38x26; 30x17, av. 1.03x.63 mm.
Feldspar 28x8; 23x8; 27x6, av. .78x.22 mm.
Augite 26x20; 42x40; 21x15, av. .89x.75 mm.

Sp. 15355. Hole 8 at 235 feet from surface. Rather low angled feldspar; 0°; 0°-12°; olivine changed into mica-like substance streaked with matter nearer chlorite (bowlingite?).

Grain

Olivine 17x10; 38x28, av. .91x.63 mm.
Feldspar 22x4; 22x7; 63x16, av. 1.07x.27 mm.
Augite 63x30; 52x45; 80x40, av. 1.95x1.15 mm.

Sp. 15356. Hole 8 at 250 feet from surface. Poikilitic augite; more basic feldspar; ex. 11°-8°; 36°-20°; 18°-16°w37°-39°; 20°-30°w13°; 15°w33°-36°, i. e., labradorite. Distance from margin—upper 52 feet, below 22 feet.

Grain

Olivine 78x40?; 70x35; 42x35; 61x30, av. 2.09x1.16 mm.
Feldspar 22x6; 30x7; 28x5, av. .80x.18 mm.
Augite 75x65; 140x135; 190x140, av. 4.05x3.40 mm.

Sp. 15357. Hole 8 at 258 feet from surface. One big phenocryst of feldspar and large altered olivine.

Grain

Olivine 32x25; 25x25; 30x15, av. .87x.65
Feldspar 230x55; 15x5; 23x6; 27x6, av. 2.45x.60
Augite 80x70; 105x80; 140x60, av. 3.25x2.10.

Such occasional large phenocrysts of feldspar are found rarely in the greenstone, also on the S. side of Washington Island at the end of Isle Royale and near the horizon of the Pewabic Lode both at the Quincy and Franklin Junior Mines. It is evidently an eocrystal.

Sp. 15358. Hole 8 at 270 feet from surface. Poikilitic; feldspar altered and changed to greenish fibres.

Grain

Olivine much decomposed

Feldspar 20x6; 23x5; 18x7; 20x5, av. .62x.19.

273-330; (Ss. 15359-64). MELAPHYRE, ophite; like the flow (56) (332) above. Compare Eagle River 73 and T. 5 flow 14.

Sp. 15359. Hole 8 at 273 feet from surface. Fine grained microlitic amygdaloid glassy. At margin 273.

Grain

Feldspar phenocrysts 11x3; 21x3.5; 27x5, av. .59x.11 mm.

Sp. 15360. Hole 8 at 280 feet from surface. Dubious olivine pseudomorphs of clustered iron oxides. Labradorite extinctions 16°-w41°-36°: 32°-24°; 23°-w40°-36°.

Grain

Olivine 22x18; 62x53?; 27x27, av. 1.11x.98 mm.

Feldspar 14x2; 35x4; 30x5, av. .79x.11 mm.

Augite 120x60; 192x120; 265x168, av. 5.77x3.48 mm.

Sp. 15361. Hole 8 at 300 feet from surface. Labradorite extinctions 27°-26 38°-36°; 19°-27°-27°; 14°-12°w34°-24°.

Grain

Olivine 24x20; 30x27; 40x25, av. .94x.72 mm.

Iron oxide little, mainly with olivine

Feldspar 19x6; 28x3; 40x15, av. .87x.24 mm.

Augite 120x80; 160x90; 125x120, av. 4.05x2.90 mm.

Sp. 15362. Hole 8 at 309 feet from surface. Poikilitic, labradorite extinction 14°-20°w23°-32°.

Grain

Olivine 20x15; 37x32; 28x22, av. .85x.69

Feldspar 24x5; 20x9; 24x5, av. .68x.19

Augite 120x60; 168x110; 100x83, av. 3.88x2.53.

Sp. 15363. Hole 8 at 326 feet from surface. Some other mineral beside augite is poikilitic some secondary mineral; labradorite extinctions—Baveno twin 48-46°w18°-18°; 20°-20°; 43°-48°w23°-22° to 27°; 18°-25°; 36°-37°; 5°-10°w29°-40°.

Grain

Olivine 17x10; 20x10; 20x15, av. .57x.35 mm.

Feldspar Baveno twin 45x40; 18x7; 21x3; 20x4, av. .97x.45 mm.

Augite 30x17; 45x15; 30x28, av. 1.05x.50 mm.

Sp. 15364. Hole 8 at 330 feet from surface. Microlitic porphyritic amygdaloid; some feldspar much smaller with 0 ex.; this is probably merely an overlap or gush of the same flow. At margin 330.

Grain

Olivine 24x25; 20x19; 26x26, av. .70x.70 mm.

Feldspar phenocrysts 16x3; 15x4; 17x5, av. .48x.12 mm.

330-362; (Ss. 15365-6). MELAPHYRE (31) (363)

Compare Eagle River 74, and T. 5 flow 15

Sp. 15365. Hole 8 at 332 feet from surface. Feldspar largely low angled; but partly at least labradorite, ex. 20°-24°; 4°-6°; 31°w14°-14°; not much augite.

Grain

Olivine 20x14; 16x10; 20x18, av. .56x.42 mm.

Feldspar 18x3; 17x4; 15x4, av. .50x.11 mm.

Augite 15x10; 17x15; 17x12, av. .49x.37 mm.

Sp. 15366. Hole 8 at 362 feet from surface. Yellow or glassy, microlitic, porphyritic; contact with sediment; extinction angles 42°-46°w25°; 27°-35°; 22°-15°; Baveno 34°-30°. At margin 362.

Grain

Olivine 30x15; 29x14; 20x15, av. .79x.44 mm.

Feldspar phenocrysts 7x3; 10x2; 10x2; also fibres, av. .27x.07 mm.

Augite none.

362-377; (Ss. 15367-8). MELAPHYRE (15) (378)

The above four flows steadily increasing in their relative thickness toward the top flow, seem to belong to the same type. Though belonging to the ophites rather than to the porphyrites, they have peculiar microscopic characters of their own, and are not very ophitic. The same group of feldspathic ophites are noticeable in the Tamarack shafts above the Conglomerate T 5-b 23 which we call the Pewabic West. The Eagle River beds 70 to 79 almost certainly represent the groups.

Sp. 15367. Hole 8 at 375 feet from surface. Decomposed.

Grain

Olivine 15x15; 12x10; 20x10, av. .47x.35 mm.

Feldspar 19x2; 14x4; 21x2, av. .54x.08 mm.

Augite 10x8; 7x7; 10x5, av. .27x.20 mm.

Sp. 15368. Hole 8 at 377 feet from surface. Microlitic porphyritic with skeleton feldspar; ex. 26°; 31°; 6°; 21°. At margin 377 ft.

Grain

Olivine 30x22; 20x16; 17x14, av. .67x.52 mm.

Feldspar 5x0.1; 7x0.2; phenocryst 7x2.

d 8.377-419; (Ss. 15369-73). Pewabic West, (Conglomerate No. 16) 41 (419)

SANDSTONE; red, with 1 foot of conglomerate at the bottom; in general quite uniform in grain; dark chocolate red; sometimes brecciated, with small red veins; the conglomerate at the base contains some felsitic debris.

Dips measured on drill cores 13°, 14½°, 15°, 16°, 15° cross-bedding of 23°. It is noticeable that the dips thus obtained from drill cores tend to be larger than those from correlations, and this fine grained sandstone furnishes some good observations. Three explanations for this want of agreement are possible,—

(1) The drill holes may curve to the north. They are not likely under the circumstances, however, to curve in this particular way, if they do, the effect should regularly be more marked toward the bottom.

(2) The conditions of deposit may have been such that the sandstone was formed in some measure by accretions, building from northwest to southeast, so that each of the laminae of which a bed was composed had originally a slight dip to the south greater than that of the bed itself as a whole. This is quite likely and is in harmony with the geological position of Isle Royale, with a mass of Archean land to the northward of it and with Chamberlin's explanation of the apparently great thickness of the Keweenawan.

(3) The difficulty may be with the correlations, which may have been made to give too flat dips by faults not otherwise to be detected, which run between the drill holes and throw the south side up. This is quite within the range of possibilities.

This sandstone is a more thorough sandstone than any other of like size in the series, and its course seems to be marked by a line of depression from Grace Harbor and its creek through to the northeast end of the island, as indicated on the map Plate I. The base of this bed is about (750) feet below the top of the bed (10,426) that we have correlated with Marvine's bed, No. 45, and would appear to represent the "first sandstone below the ashbed," which Marvine supposes to lie in a covered place (506) feet stratigraphically below bed No. 65, (993 feet below 45) which is about the usual rate of shrinkage between Isle Royale and Keweenaw Point:

On this assumption the sediment at No. VIII, 440 feet, just below, would do well for No. 85 of the Eagle River section, which Marvine seems to correlate with the "Pewabic West," and says is 767 feet below the slide above the Ashbed, and is No. 16 of his plate of conglomerates facing p. 60. It is probably more nearly true to the facts, to correlate both our sandstones together as indicating a weakening in igneous activity represented by sandstones in the Eagle River section scattered from bed No. 76 to bed No. 85. There can be little doubt that it corresponds, too, to that Conglomerate T. 5 b 23 which is so persistent in the Tamarack shafts and as here is generally sandy on top.

Sp. 15369. Hole 8 at 380 feet from surface. Fine grained sediment, rounded grains of augite, etc.

Grain

Augite 34x16; 16x12, av. .83x.46.

Sp. 15370. Hole 8 at 397 feet from surface. Similar; sandstone.

Sp. 15371. Hole 8 at 415 feet from surface. Similar, with fragments of microlitic porphyrite.

Sp. 15372. Hole 8 at 419 feet from surface. Coarser, calcareous cement, poikilitic and microlitic fragments; oligoclase brotocrysts; one quartz phenocryst; conglomerate.

Sp. 15373. Hole 8 at 420 feet from surface. Calcareous with zeolites and calcite vein streaked into prehnite; decomposed top of flow below perhaps. This may be 15273.

420-431; (Ss. 15374-5). MELAPHYRE, porphyrite; about 4 feet (11) (11) amygdaloidal at the top (we are back to the porphyrites once more), dark green, with reddish porphyritic crystals. Matches Marvine's bed No. 82, T. 5 b 25 flow 18.

Sp. 15374. Hole 8 at 423 feet from surface. Glomeroporphyritic feldspar; little or no augite; microlitic base; ex. 6°-8°w-13°; 4°-10°-6°; 3°-0°w17°.

Grain

Olivine 0

Iron oxide 9x4

Feldspar phenocrysts 40x30; 40x20; 47x35, av. 1.27x.85.

Sp. 15375. Hole 8 at 431 feet from surface. Glass base; contact with a sediment; perhaps a clasolite. Margin at 431 ft.

Grain

Olivine?

Feldspar phenocrysts 48x30; 70x(20-40); 50x25, av. 1.68x?

431; SEDIMENT; contact; Marvine's bed No. 83?

431-440; (S. 15376) MELAPHYRE, porphyrite; about 2 feet (9) (11) (20) amygdaloidal at top; matches Marvine's bed No. 84, except for size.

Sp. 15376. Hole 8 at 436 feet from surface. Glomeroporphyritic chloritic; irregular amygdaloidal; coarse grained cavities; nevaditic ex. 13°-4°-4°.

Grain

Olivine (rare) 10x5

Iron oxide 20x1; 13x1; 20x1 in chlorite, av. .53x.03 mm.

Feldspar phenocrysts 25x16; 42x25; 42x20, microlites 12x1.5; av. 1.09x.61 mm.

Augite 6x6; 4x3; 6x2; 5x4, av. .17x.12 mm.

440-444; (Ss. 15377-9). SHALE, red. The grain is so fine (4) (24) that this bed was taken to be a fine grained trap until the microscope revealed its character. Marvine's Eagle River bed 85.

Sp. 15377. Hole 8 at 440 feet from surface. Fine grained sediment; clasolite? Margin 440.

Grain

Augite granules 3x2.

Sp. 15378. Hole 8 at 443 feet from surface. Fine grained sediment; red shale (ash bed) ? or sandstone.

Sp. 15379. Hole 8 at 444 feet from surface. Fine grained sediment. Margin at 444.

444-486? (Ss. 15380-1). MELAPHYRE, porphyrite; very acid (41) (65) specimen; little olivine or augite, and might be classed with more salic rocks; amygdaloidal for 5 feet at the top, then a typical greenish gray trap. The exact bottom of this flow is a little uncertain. It lies on another flow of similar lithological character (both remarkable, under the microscope, for the scarcity of olivine), both of which appear to occur at the top of drill hole No. VII, to which we therefore pass, making No. VIII, 486 feet equal to No. VII, 10 feet. It is obvious that as the sandstones above No. VIII, 444 feet, do not appear in No. VII, the correlation of the top of No. VII cannot be sought above these sandstones. If we figure out the dip as before[1] we find it differs only .002 from the tangent of the dip as computed between Nos. VIII and IX.

Sp. 15380. Hole 8 at 450 feet from surface. Glomeroporphyritic idiomorphic augite like 15376; the apparently porphyritic grain of iron oxide has bands of different lustre of iron hydrate and hematite? like an agate?; feldspar ex. 5°-9°w5°; 0°-6°.

Grain

Iron oxide 80x75; 9x1; 5x4; 9x1, av. .85x.77 mm.

Feldspar 105x105; 40x17; 66x23; microlites 5x1; 5x1, av. 1.43x.98 mm.

Augite 5x1; 4x3; 7x3; 5x2, av. .17x.07 mm.

Sp. 15381. Hole 8 at 471 feet from surface. Rather decomposed; at 486 ft. was amygdaloidal bottom.

Grain

Olivine 10x8; 10x7, av. .33x.25

Feldspar 65x32; 50x27; 10x1; 10x1, av. 1.2x.50

Augite 2x2; 4x3; 5x3, av. .11x.08.

Sp. 15282. Hole 7 at 2 feet from surface. Glomeroporphyritic with microlitic ground and low angled feldspar, little augite.

Feldspar phenocrysts 55x45; 63x30; 80x35, av. 2.09x1.10 mm.; microlites 5x1; 7x1; 7x1, av. .19x.03 mm.

Augite 6x3; 3x2; 2x2, av. .11x.07 mm.

Sp. 15382. Hole 8 at 491 feet from surface. Glomeroporphyritic; fine grained amygdules; microlitic base; small angled feldspar; extinction angles 14°-11°; 4°; 26°-12°; 7°- (-2°); 12°-13°-17°. At margin.

Grain

Feldspar phenocrysts 40x8; 37x20, av. 1.2x.46 mm.; microlites 4x1.

The amygdules contain prehnite, which is illustrated in Fig. 24 of Volume VI, Part 1.

Sp. 15383. Hole 8 at 496 feet from surface. Glomeroporphyritic as before with sandstone with poikilitic calcite cement, very ferruginous.

[1](486–10)=476 minus the excess of altitude of No. VIII over No. VII (262.6–376.3) 114=362 feet, which divided by the distance, 1,584 feet, is 0.229, again the tangent of about 13°, (really about 0.5 less).

Grain

Feldspar 35x15; 65x52; 26x13, av. 1.26x.80 mm.

Augite?

Sp. 15384. Hole 8 at 504 feet from surface. Glomeroporphyritic feldspar but little augite in ground mass; feldspar extinction angles 8°-1°; phenocrysts 29°-16°; 14°-0°; 22°; 0°.

Grain

Iron oxide 3x2

Feldspar (Baveno twins) 34x15; 90x60; 80x60, av. 2.04x1.35 mm.

Augite 7x6.

Sp. 15385. Hole 8 at 505 feet from surface. Distinctly finer grained and more decomposed; prehnitic (R<V, +2 V small).

DRILL HOLE No. VII.

10?-83?; (Ss. 15283-8). PORPHYRITE; like the flow above, about 6 feet at the top amygdaloidal; has irregular amygdaloidal streaks, and occasional seams of laumontite; the porphyritic feldspar groups are very well marked.

Sp. 15283. Hole 7 at 12 feet from surface. Similar to 15382.

Grain

Feldspar 7x1; 8x1; 8x1, av. .23x.03 mm.

Augite 2x2; 2x2, 3x1, av. .07x.05 mm.

Sp. 15284. Hole 7 at 25 feet from surface. Coarser and more decomposed; 'reddish specks'' are probably altered olivine (bowlingite?)

Grain

Feldspar 8x1; 10x1; 12x2, av. .30x.04

Augite grain unrecognizable.

Sp. 15285. Hole 7 at 32 feet from surface. Feldspar more uniform in grain; much iron oxide; altered olivine?

Grain

Feldspar phenocrysts and microlite shade into each other (seriate)

Augite 4x4; 10x10; 5x3; 8x5. av. .22x.18.

Sp. 15286. Hole 7 at 36 feet from surface. Glomeroporphyritic feldspar; idiomorphic augite.

Grain

Feldspar 10x2; 12x2; 14x2, av. .36x.06 mm.

Augite 6x5; 10x3; 4x3, av. .20x.11 mm.

Sp. 15287. Hole 7 at 60 feet from surface. Similar; somewhat decomposed and finer.

Grain

Feldspar 6x2; 7x1; 9x1.5, av. .22x.04 mm.

Sp. 15288. Hole 7 at 68 feet from surface. Similar but finer grained; ground mass feldspar not marked; much large feldspar; olivine probably. Margin at 83 ft.

Sp. 15292. Hole 7 at 109 feet from surface. Very fine grained microlitic amygdaloid; contact with a sediment, the grains of which can be seen in ordinary light but in polarized light they have no individuality (except in the distribution of iron oxides) hence perhaps originally glass.

Grain

Iron oxide 2x1; 1x1; .2x.2, av. .03x.02

Feldspar 5x0.2; 7x1; 6x0.5, av. .18x.01.

Sp. 15291. Hole 7 at 94 feet from surface. Much porphyritic low angled feldspar; ex. 0°-23°; 0°-0°; 0°-12°; 15°-w5°-4°.

Separation of phenocrysts and ground mass in grain is not practicable; feldspar of ground mass 7x2+?

Augite decomposed or very small; not large.

83-109; (Ss. 15289-92). PORPHYRITE, amygdaloidal; *copper* (26) (91) in amygdules (at 83 feet), and in veins with prehnite (at about 90 feet); analcite and chlorite also occur in amygdules; the amygdules are often but partly filled, and lined with tufted chlorite and white crystals. Laumontite also occurs. Though the appearance of copper may be accidental and due even to the presence of a transverse vein, it is worth noting that we are getting near to the horizon of the "Pewabic Lode" worked in the Quincy Mine.

Sp. 15289. Hole 7 at 83 feet from surface. Prehnitic amygdaloid; fine grained.

109; Seam of SEDIMENTARY matter 0 (91)

109-130; (Ss. 15293-4). PORPHYRITE, amygdaloidal; like the (20) (111) flow above, with alternating bands more or less conspicuously porphyritic; possibly more than one flow; at 127 feet narrow vein of *copper*, prehnite and quartz.

Sp. 15293. Hole 7 at 119 feet from surface. Much of the large low angled feldspar; slightly amygdaloid.

Grain

Olivine 6x5; 8x4; 8x6, av. .22x.15

Feldspar phenocrysts 38x17; 80x27; 33x25, av. 1.51x.69 mm.; microlites very small.

Sp. 15294. Hole 7 at 130 feet from surface at margin. Prehnite; very amygdaloidal; contact with sediment.

Grain

Feldspar microlites 3x0.1.

At 130 seam of SEDIMENTARY matter or fluccan; much prehnite.

130-162; (Ss. 15295-6). PORPHYRITE, amygdaloidal, as above; (31) (142) at 160 feet seam of *copper* in cubes, with prehnite and quartz.

Sp. 15295. Hole 7 at 144 feet from surface. Delessite and amygdules.

Grain

Olivine 11x10; 10x10, av. .35x.33 mm.

Iron oxide 11x1; 5x6; down to 0

Feldspar various sizes, ground mass glass.

Sp. 15296. Hole 7 at 153 feet from surface. Augite greenish, more idiomorphic; low angled feldspar; apparently some interstices with fine grained feldspar.

Olivine 10x8; 30x25?; 10x10; some olivine smaller; av. .55x.21 mm.

Iron oxide 10x10; 23x3, av. .55x.21 mm.

Feldspar phenocrysts 30x35; 43x18, av. 1.21x.88 mm—; and smaller

Augite 28x13; 57x25; 53x42, av. 1.38x.80 mm.

162-197; (Ss. 15297-8). MELAPHYRE, porphyrite (34) (176)

Sp. 15297. Hole 7 at 162 feet from surface. Marginal porphyritic amygdaloid; all impregnated with quartz. Margin at 162 ft.

Grain

Iron oxide makes a black ground mass

Feldspar 7x.1; 8x2; 8x.2, av. .23x.05.

The section just above is so coarse that there are possibly some misplaced samples here, and from 130 ft. to 197 ft. may be one flow.

Sp. 15298. Hole 7 at 180 feet from surface. Low angled andesite feldspars, idiomorphic augite, altered olivine with iron oxide grains.

Grain

Olivine (altered) 25x10; 24x17; 12x10, av. .61x.37 mm.

Iron oxide 12x1; 15x15, av. .45x.26 mm.

Feldspar 68x30; 45x15; 26x25, av. 1.39x.70 mm.

Augite 45x25; 9x6; 17x3; 16x12, av. .72x.38 mm.

197. Flinty-looking epidotic seam, a mass of BRECCIATED prehnite and quartz. It will be observed that copper has been noted in four places in the beds immediately above, and that the amygdaloids are quite rich in minerals. It seems quite possible that here at 197 feet is the center of the VEIN which has been a channel for this impregnation. There may be a fault here.

In such case the copper would come from a cross fissure, but it must not be forgotten that we are just about at the horizon here of the PEWABIC LODE, and it at least suggestive to find copper. Farther testing would seem desirable.

197-199; (Ss. 15299-300). AMYGDALOID. (2) (178)

Sp. 15299. Hole 7 at 197 feet from surface. Brecciated mass of prehnite and quartz; appears almost sedimentary in places; there are numerous outlines of glass fragments.

Sp. 15300. Hole 7 at 198 feet from surface. Porphyritic microlitic amygdaloid; skeletal feldspars; one feldspar brotocryst has ex. 2°-4° with 11° in altered part.

This is the characteristic texture of thin flows and margins long narrow feldspars, forked and in sheaves.

Grain

Iron oxide black dust

Feldspar phenocrysts 40x22, microlites 10x1; 12x.2; 10x.1, av. .32x.01 mm.

199; (S. 15301). Seam of SEDIMENTARY matter; apparent dip (0) (178) 21°.

Sp. 15301. Hole 7 at 199 feet from surface. Bands of stratified and clastic? fragments but full of epidote and chlorite and altered contact sediment; not so markedly ashy as No. 15299.

199-210; (Ss. 15301-3). AMYGDALOID; much decomposed, with (11) (189) zeolites, etc.

Sp. 15302. Hole 7 at 200 feet from surface. Perhaps triple generation of feldspar ex. 18°-20°; 13°-10°; 6°-5°w11°; 6°-8°w19°-?

Grain

Feldspar phenocrysts 60x15; microlites 11x1; ?9x1; 12x1.

Sp. 15303. Hole 7 at 210 feet from surface. Very amygdaloidal; porphyritic; zeolites and calcite. Margin at 210 ft.

Grain

Feldspar phenocrysts 23x16; microlites 10x1.2; 10x1; 11x1, av. .32x.03

Augite probably too fine grained for observation and also decomposed

210-221; (Ss. 15304-5). PORPHYRITE, amygdaloidal; like the (11) (200) rocks above near 130 feet.

Sp. 15304. Hole 7 at 215 feet from surface. Low angled feldspar; altered olivine? very little augite; very chloritic. The feldspar is in aggregates and very coarse. Is this one of the green nodules?

Grain

Olivine 15x15; 7x6; 11x8, av. .33x.29 mm.

Iron oxide 19x1; 18x.5; 7x.2, av. .44x.03 mm.

Feldspar phenocrysts 67x42; 53x34; 128x52, av. 2.48x1.28 mm.

Augite (2x1; 2x1; 1x1 questionable), av. .05x.03 mm.

Sp. 15305. Hole 7 at 215 feet from surface.

221-302; (Ss. 15306-15). Feldspathic ophite; intermediate type, (79) (279) quite feldspathic, yet in traces ophitic, with red feldspathic seams, and like Marvine's bed No. 87, which is one of Irving's types of the "ordinary olivine-free" diabase (Copper-Bearing Rocks, Mon. V. U. S. Geol. Sur., p. 65) and is analyzed above. It is quite likely to be the foot of the Pewabic Lode (see Fig. 40).

Sp. 15306. Hole 7 at 221 feet from surface. Porphyritic with altered glassy pumiceous; note chloritic base; cf. 15295 secondary additions to porphyritic feldspar in ground small feldspars only around amygdaloid.

Grain

Feldspar phenocrysts 48x42; 22x25; ground mass 2 to 3x0.1

Augite 0.

Sp. 15307. Hole 7 at 230 feet from surface. Much feldspar; ex. 23°-17°; 18°-12°; 18°-18°; coarse grained and not porphyritic except around amygdules; elsewhere microlitic chloritic. Distance from margin 9.

Grain

Olivine 10x8; 11x10; 12x11, av. .33x.29 mm.

Iron oxide 13x1; 10x1, av. .38x.03 mm.

Feldspar microlites 12x1; phenocrysts 70x40, av. 1.36x.68 mm.

Augite 15x12; 10x10; 12x12, av. .37x.34 mm.

Sp. 15308. Hole 7 at 237 feet from surface. Similar. Distance from margin 16.

Grain

Olivine 28x25; 15x7; 12x9, av. .55x.41 mm.

Iron oxide 13x1; 17x3; 18x1.5, av. .58x.05 mm.

Feldspar phenocrysts 32x6; 44x6; 43x8, av. 1.19x.20 mm.

Augite 35x20; 18x10; 53x13, av. 1.06x.43 mm.

Sp. 15309. Hole 7 at 246 feet from surface. Very coarse and augitic; very much decomposed, probably doleritic. Distance from margin 25.

Grain

Iron oxide 45x2; 40x1½; 57x2, av. 1.42x.05 mm.

Feldspar 30x5?

Augite 45x40; 27x25; 80x23, av. 1.52x.88 mm.

Sp. 15310. Hole 7 at 258 feet from surface. Feldspar ex. 17°-18°w0°; poikilitic augite.

Grain

Olivine 16x18; 24x10, av. .60x.46 mm.

Iron oxide 12x4; 12x1; 24x13, av. .48x.18 mm.

Feldspar 47x22; 42x10; 68x20, av. 1.57x.52 mm.

Augite 190x150; 200x70; 160x80, av. 5.50x3.00 mm.

Sp. 15311. Hole 7 at 262 feet from surface. Coarse; much decomposed; presence of olivine doubtful; prehnitic.

Grain

Olivine 15x13?

Iron oxide 10x1

Feldspar 42x17

Augite 65x35; 80x10, av. 2.41x.75.

Sp. 15312. Hole 7 at 264 feet from surface. Still coarser decomposed; poikilitic; hard to make out, is there possibly a contact or slide here?

Grain

Olivine 20x15?

Iron oxide 35x5; 13x10; 14x15, av. .62x.30 mm.

Feldspar 40x15

Augite 65x53.

Sp. 15313. Hole 7 at 268 feet from surface. Low angled feldspar ex. 2°-8°w 0°-7°; 10°-3°w5°; poikilitic augite.

Grain

Olivine 24x16; 15x14; 40x21, av. .79x.51 mm.

Iron oxide 30x2; 24x2; 23x1, av. .77x.05 mm.

Feldspar 43x17; 50x40, av. 1.53x.95 mm.

Augite 105x100; 100x95; 112x60, av. 3.17x2.55 mm.

The grain of 15313 to 15315 is plotted under 2 in Fig. 16 of the Isle Royale Report. It is exceptionally coarse at the bottom.

Sp. 15314. Hole 7 at 290 feet from surface. Labradorite ex. 9°-4°w24°-26°; 40°-34°w18°-15; more basic at center; poikilitic augite. These and the following specimens appear more red and ferruginous as is often true near the base.

Grain

Olivine 20x18; 20x15; (43x35?)

Iron oxide 18x1; 15x2; 12x2, av. .45x.05 mm.

Feldspar 36x13; 20x6; 40x15, av. .96x.34 mm.

Augite 125x60; 66x60; 105x85, av. 3.96x2.05 mm.

Sp. 15315. Hole 7 at 302 feet from surface. Much altered olivine which at one side becomes fine grained; microlitic augite small. At margin 302.

Grain

Olivine 15x12; 12x8; 17x9, av. .44x.29

Feldspar phenocrysts 30x15; 37x15; 40x5, av. 1.07x0.35 mm.; final generation of microlites 2x0.2.

302-324; (S. 15316). AMYGDALOID. (21) (300)

Sp. 15316. Hole 7 at 302 feet from surface.

324; (S. 15317). VEIN; carries *copper* crystals, prehnite and quartz.

Sp. 15317. Hole 7 at 324 feet from surface. Thoroughly decomposed; quartz, prehnite and poikilitic quartz replacing microlitic fragments.

324-337. AMYGDALOID. (13) (313)

337-375; (Ss. 15318-20). PORPHYRITE, amygdaloidal; fine (37) (350)

grained and full of small chloritic amygdules and chloritic seams, which simulate bedding and may mark flow lines. Dip 17° to 18° at 371 feet, 23° at 373 feet.

Sp. 15318. Hole 7 at 337 feet from surface. Rather decomposed with microlitic texture.

Grain

Olivine 12x8; 17x12; 16x15, av. .45x.35 mm.

Iron oxide 3x3; 8x7; 5x4, av. .16x.14 mm.

Feldspar phenocrysts 25x10; 25x10; 40x20, av. .90x.40 mm.

Augite none visible.

337; (S. 15319). Vein and perhaps contact; carries *copper*, etc.

Sp. 15319. Hole 7 at 371 feet from surface. Fine grained microlitic amygdaloid.

Grain

Iron oxide 4x2; 7x5; 2x1, av. .13x.08 mm.

Feldspar 8x1; 10x2; 3x.2, av. .21x.03.

375-394; (Ss. 15320-1). PORPHYRITE, amygdaloidal; analcite (19) $\frac{350}{(369)}$

in cavities at 375 feet; generally fine grained with chloritic amygdules.

Sp. 15320. Hole 7 at 375 feet from surface. Contact of porphyritic microlitic scoriaceous margin with sediment.

Grain

Feldspar apparently low angled; size of microlites 3x.2; 6x.2; 2.5x.1; phenocrysts? 9x3, av. .16x0.02, often larger.

394-423; (Ss. 15321-4). MELAPHYRE; intermediate form, more (28) (397)

basic than adjacent flows, and somewhat ophitic.

Sp. 15321. Hole 7 at 394 feet from surface. Apparently contact of two microlitic flows, with a seam of sediment between.

Grain

Feldspar microlites 24x.1; 9x4; 27x2 or 3x.5.

This shows well the contrast between top and bottom of a flow. Note the fragment enclosed in the sediment.

Sp. 15322. Hole 7 at 403 feet from surface. Poikilitic but with low angled feldspar and semi-idiomorphic augite.

Grain

Olivine 12x9; 25x20; 20x13, av. .57x.42 mm.

Iron oxide 9x2; 16x1; 15x1, av. .40x.04 mm.

Feldspar 25x8; 15x8; 31x8, av. .71x.24 mm.

Augite 43x13; 30x28; 40x30, av. 1.13x.71 mm.

Sp. 15323. Hole 7 at 415 feet from surface. Big aggregates of altered olivine; delessite and miarolitic texture with interstices lined with radiating chloritic fibres. Olivine 62x60$\pm$, 20x15.

Grain

Iron oxide 21x2; 7x3; 22x2, av. .50x.07 mm.

Feldspar 30x5; 20x4; 20x6, av. .70x.15 mm.

Augite 80x60; 80x60; 60x50, av. 2.20x1.70 mm.

Sp. 15324. Hole 7 at 423 feet from surface. Microlitic, porphyritic, chloritic and prehnitic amygdaloid. At margin.

Grain

Feldspar, phenocryst 10x2; microlites 5x.2, 9x1; av. .24x.03 mm.

(7) (404)

423-430. AMYGDALOID. (It is not certain that S. 15324 does not belong to this flow). I take this bed to be equivalent to No. VI, 74-81 feet, and we pass from No. VII, 430 feet, to the record of No. VI. While immediately below these points, in No. VII and in No. VI respectively, there is a very peculiar bed of porphyry and felsite tufa, which makes the correlation a good one, the beds above this bed (i. e., above No. VI, 81 feet and No. VII, 430 feet) do not match very well. This bed of porphyry tufa is without doubt the "Mesnard epidote" which lies directly over the Greenstone and may be recognized as a red jasper looking rock in many cross-sections in the Franklin Mine Fig. 40 and was also struck in Tamarack shaft 1 at 460 feet, and presumably goes through the "covered" gap just above. It is taken by us as the base of the "ashbed" series. Hence we should be at a point which according to our correlations should correspond to 1030 feet below the "slide" at Marvine's bed No. 63 and 334 feet more or less below the sandstone of Marvine's bed No. 80, while the corresponding thicknesses in our Isle Royale column are about 900 feet

and 404 feet rather greater than we should expect, for the increase in thickness of Keweenaw Point over Isle Royale is generally greater than this indicates. We are led then to suspect faulting in No. VII, by which the series may have been duplicated and copper segregation aided. There are a number of places where faulting might occur in No. VII, but we have no means of determining its amount. Such faulting might account for the disparities between drill holes Nos. VI and VII.

W. W. Stockly reports a "break" as apparent near No. VII, running nearly south (and thus liable to pass between No. VI and No. VII), and throwing the east side down. Such a fault as that would, if it were a normal fault, hade to the east, and if it passed through the middle of drill hole No. VII, would not disturb the correlations and dips at all, but would cause us to leave out some beds unawares. In No. VII however, the column as we have seen seems to be exceptionally full, so that we cannot attribute any great effect to such a fault. If it did not pass through the bottom of No. VII, and according to its strike it should not, the effect of such a fault would be to make the dip derived from correlations between Nos. VII and VI greater than it really is.

But the dip derived from the correlation No. VII, 430 feet, with No. VI, 81 ft., is 13°, practically the same dip as found between No. VIII and No. VII.

Sp. 15325. Hole 7 at 435 feet from surface. Epidote and quartz; very fine grained; contact; concave ash forms.

Sp. 15326. Hole 7 at 435 feet from surface. Sediment of brecciated quartz porphyry; not plain. A fragment of microlitic porphyrite and of a quartz phenocryst enclosed. This I am inclined to correlate with the felsite of the Porcupine Mountains or Chippewa felsite, which extends at least from south west of Black River (Fig. 55) to the Fire Steel River (Plate XII), and may well be expected to scatter its ash as far again.

Sp. 15327. Hole 7 at 435 feet from surface. Quartz porphyry tufa, not fluidal; traces of original perlitic texture; ash and sediment forms.

DRILL HOLE No. VI

Above the correlation line we have—

0-17; (Ss. 15226-8). MELAPHYRE; shows occasional large porphyritic plagioclase crystals; such crystals occur not only in the "Greenstone" but above it on the S. side of Washington Island and near the Pewabic lode; is in general of intermediate type, like No. VIII, 221-302 feet.

Sp. 15226. Hole 6 at 8 feet from surface. Poikilitic augite; much feldspar, ex. 10°-9°w33°-37°; 12°-?w34°-38°.

Grain

Olivine 11x9; 45x23; 24x9. av. .80x.41 mm.
Iron oxide 15x13?
Feldspar 42x17; 36x16; 60x20, av. 1.38x.53 mm.
Augite 75x50; 140x120; 105x105, av. 3.20x2.75 mm.

Sp. 15227. Hole 6 at 15 feet from surface. Similar to 15226.

Grain

Olivine 12x10; 13x8; 30x10, av. .55x.28 mm.
Feldspar 78x20; 25x13; 40x7, av. 1.43x.40 mm.
Augite 220x100; 64x40; 50x20, av. 3.34x1.60 mm.

Sp. 15228. Hole 6 at 17 feet from surface. Porphyritic microlitic amygdaloid; moderate angled feldspars.

Grain

Iron oxide from dust to 9x1.

Feldspar 11x1; 12x2; 11x3, av. .34x.06 mm.

Augite or olivine granules 2-3.

17-25; (Ss. 15229-30). PORPHYRITE, amygdaloidal; chloritic and laumontitic.

Sp. 15229. Hole 6 at 20 feet from surface. Little poikilitic amygdaloid; feldspar rather decomposed and in this Sp. 15230 seriate; chalcedonic druses.

Grain

Iron oxide and altered olivine associated, 4x6?

Feldspar 14x6; 40x12; 42x11, av. .96x.29 mm.

Augite 80x50; 25x20; 22x12, av. 1.27x.82 mm.

Sp. 15230. Hole 6 at 25 feet from surface. Fine grained amygdaloid; low angled feldspar of various sizes; not markedly porphyritic.

Grain

Iron oxide 4-5; 4?

Feldspar 17x2; 15x2; 30x7, av. .62x.11.

25-59; (Ss. 15231-3). PORPHYRITIC, amygdaloidal; with (30) chlorite or laumontite amygdules on red ground; occasional large porphyritic plagioclases; tubular amygdules at the bottom of bed.

Sp. 15231. Hole 6 at 32 feet from surface. Finer grained with various spots of finer grain. It has a very rare and peculiar texture growing coarser radially away from frequent centers.

Grain

Iron oxide 3x2; 4x4, av. .03x.03 mm.

Feldspar 58x19; 38x14; 20x9; 7x5, av. .76x.29 mm.

Sp. 15232. Hole 6 at 47 feet from surface. Much altered olivine and feldspar; little augite.

Grain

Olivine 10x10; 13x13; 10x13, av. .33x.36

Iron oxide 14x2; 9x0.5; 10x2, av. .33x.04

Feldspar 46x15; 42x5; 33x5, av. 1.21x.25

Augite 20x8; 20x9; 7x4, av. .47x.21.

Sp. 15233. Hole 6 at 58 feet from surface. Finer grained and especially around amygdaloid; low angled feldspar; this is the bottom and there are pipe amygdules.

Grain

Olivine 42x33

Iron oxide 12x1, fine grained but the long iron oxide may be a secondary formation.

Feldspar phenocrysts 58x17; 12x7; 13x5; 13x7, av. .80x.30.

59-67 or 72; (Ss. 15234-5?). PORPHYRITE, amygdaloidal; very porous; cavities lined with crystals.

Sp. 15234. Hole 6 at 59 feet from surface. Contact.

Grain

Feldspar 3 to 4x0.1.

Sp. 15235. Hole 6 at 72 feet from surface. Very much decomposed; fine grained amygdaloid.

72-81; (Ss. 15235-6). AMYGDALOID. Cavities with fillings of radiating chlorite fibres.

Sp. 15236. Hole 6 at 81 feet from surface. Contact of glassy, fine grained microlitic amygdaloid and a sediment of black fragments with the concave splintery forms of ash. Distance from margin 0.

Grain

Olivine none?

Iron oxide red to opaque

Feldspar phenocrysts 20x3; 25x5; 17x7, av. .62x.15 mm.

Augite none.

(404)

6. 81-91; (Ss. 15237-42); 7. 430-435; (Ss. 15325-15327). (10) (414)

PORPHYRY TUFF. The Mesnard "epidote" bed. At the top there is a bed showing under the microscope the conchoidal forms of glass ashes, but in general the signs of sedimentation are very obscure, so much so that from mere inspection with the unaided eye I could hardly be sure that I was not examining a brecciated porphyry flow with some enclosures. This does not appear like a water-worn conglomerate, but like a contemporaneous tuff. It may be correlated with the "jasper," 67.7 feet above the Allouez conglomerate at the Franklin Junior Mine Franklin 11, Fig. 40 (Hubbard, Proc. L. S. Mining Institute, 1894, p. 93), Arcadian 16, Fig. 41, and 460 feet down in Tamarack No. 1 shaft (Geol. Sur. of Mich., Vol. V, Pt. I, p. 112), and I think with the Chippewa felsite of the Porcupine Mountains Figs. 52-55.

Sp. 15237. Hole 6 at 83 feet from surface. Quartz porphyry and quartz? and oligoclase brotocrysts; faint signs of brecciation or sediment.

Sp. 15238. Hole 6 at 84 feet from surface. Similar to 15237.

Sp. 15239. Hole 6 at 86 feet from surface. Similar to 15238.

Sp. 15240. Hole 6 at 88 feet from surface. Quartz porphyry, perhaps pebble or possibly thin representative of Chippewa felsite.

Sp. 15241. Hole 6 at 89 feet from surface. Microlitic porphyrite with green amygdules, pebble?

Sp. 15242. Hole 6 at 90 feet from surface. Quartz porphyry or porphyrite with quartz and oligoclase phenocrysts passing into a microlitic porphyrite, something like 15241.

BEGINNING OF THE CENTRAL GROUP.

(32) (446)

91-124; (Ss. 15243-7). OPHITE, top gush? of the greenstone, but at the Franklin and numerous other sections there is a bed Franklin 12 between the Mesnard and the Greenstone. This *may* be Marvine's Eagle River Bed 90.

Sp. 15243. Hole 6 at 91 feet from surface. Microlitic, not porphyritic; amygdaloid; small altered olivine; not very low angled andesite feldspar; a little fresh olivine in this flow.

Grain

Olivine 3; 3x2; 2

Iron oxide 3x1; about size of olivine

Feldspar 5x1; 8x2; 8x1.5, av. .21x.045.

Sp. 15244. Hole 6 at 99 feet from surface. Microlitic fine grained; occasionally amygdaloid.

Grain

Olivine 2½; 2x3; 2, av. .06 mm.

Iron oxide 1.5; 4x1; 2, av. .045 mm.

Feldspar 8x1; 9x1; 7x1, av. .24x.03 mm.

Augite 4x3; 8x5; 4x4, av. .16x.12 mm.

Sp. 15245. Hole 6 at 111 feet from surface. Labradorite extinction angles 34°-33°w-16°; 10°w36°-25°; 21°-17°w38-°35°?

Grain

Olivine?

Iron oxide 5x5; 5x5; 5x4, av. .15x.14 mm.

Feldspar 12x2; 6x1; 9x2, av. .27x.05 mm.

Augite 62x30; 30x23; 35x35, av. 1.27x.88 mm.

Sp. 15246. Hole 6 at 116 feet from surface missing.

Sp. 15247. Hole 6 at 124 feet from surface. Labradorite extinction angles 24°-25°-w?-34.

Grain

Olivine in all these sections probably, about size of iron oxides

Iron oxides 4; 9; 4

Feldspar 13x1½; 14x3; 17x2, av. .44x.065 mm.

Augite 16x10; 10x10; 11x5, av. .37x.25 mm.

12(?)-363; (Ss. 15248-58). OPHITE, the Greenstone. This is the (233) (679) largest single flow that we meet. It makes the "backbone" of the island extending from Card Point to Blake Point in an almost uninterrupted ridge. Judging from the mottlings which are larger as we go northeast, (see Plate VII of Vol. VI, Part I, which is at the base of Monument rock (Plate VIII)) and from the greater height of the ridge in that direction and from other reasons, the sheet thickens toward the northeast as it does also on Keweenaw Pt. This bed is distinctly lustre-mottled, and in sharp contrast with the series of porphyrites which overlie it and make a parallel ridge that extends from a low outcrop on the south side of Grace Harbor (including also part of Washington Island, further west), north of the Island mine, Siskowit Lake and Lake Richie, to the east end of Scovill Point. The backbone ridge thus agrees in every way with the great corresponding ridge on Keweenaw Point, which is included in Marvine's beds of "diorite" (not having the use of the microscope Marvine mistook augite for hornblende) Nos. 91 to 108, from (2927) feet to (4120) feet of the Eagle River section which after personal inspection I pronounce a unit, the lighter and darker types being merely differentiations in the same flow. This is a colossal thickness for one flow (1193 ft.), but I could find no finer grained band such as would mark a contact. Moreover, if we compare the size of the coarsest mottlings near Eagle River with those of the much thinner (233 feet) section of Isle Royale, some such great thickness (see p. 147) is indicated. The drilling at the Manitou and Mandan properties (Figs. 25 and 29) confirms this diagnosis. That we should find it thinner on the island is moreover in harmony with what we have hitherto found. This same Greenstone also thins very much toward the southwest along Keweenaw Point, as shown by Marvine and by Hubbard (loc. cit p. 95). Moreover, both on Keweenaw Point and on Isle Royale, we shall find, in the series below it, similarly basic ophites predominating, while on the other hand the porphyrite type which has been so dominant above, from d X. 193 ft. down (1446 feet, approximately equal to Marvine's 1272-2840, or 1568 feet) occurs only at intervals.

Sp. 15248. Hole 6 at 139 feet from surface.

Grain

Iron oxide 4; 3; 4

Feldspar 10x2; 19x2; 14x1.5, av. .43x.05

Augite 8x5; 10x6; 18x9, av. .36x.20.

See I. R. report p. 125 Fig. 14.

See I. R. report p. 134 Fig. 18.

The grain of this flow has been the most carefully studied. That on Isle Royale is shown in Fig. 14 and Fig. 18 of the Isle Royale Report. Further observations

will be found on p. 208 of my report for 1903 from which we infer that the rate of increase of augite grain is at the margin C″=.00422 while for the central part it approaches $0.000213x^1 + .883$. This indicates exterior heated zone of only 2,400 mm. indicating that the rock was very fluid and cooled nearly to crystallization point before coming to rest.

Further observations on the grain of this flow will be found in most of the cross-sections north of Portage Lake. In some cases A is as high as .0003 to .0004.

Sp. 15249. Hole 6 at 163 feet from surface. Labradorite extinctions 17°-15°; 15°-8°w40°-35°.

Grain

Olivine 6; 6; 10
Iron oxide 5x1; 5x0.5, av. .16x.02 mm.
Feldspar 10x1.5; 10x2;14 x3, av. .34x.06 mm.
Augite 60x50; 55x45; 65x50, av. 1.80x1.45 mm.

Sp. 15250. Hole 6 at 164 feet from surface. Chlorite coated cavities, somewhat doleritic? Distance from margin 194.

Grain

Olivine 9; 8; 8
Iron oxide 4x1; 4x5; 5x1, av. .13x.07 mm.
Feldspar 11x1.5; 10x2; 10x2, av. .31x.05 mm.
Augite 100x80; 120x80; 100x90, av. 3.20x2.50 mm.

Sp. 15251. Hole 6 at 216 feet from surface.

Grain

Olivine 5; 7; 10x6; 12x6, av. .29x.17 mm.
Iron oxide 7x2; 10x5; 9x2, av. .26x.09
Feldspar 10x4; 9x3; 14x3, av. .33x.10
Augite 120x120; 195x160; 140x140, av. 4.55x4.20.

Sp. 15252. Hole 6 at 240 feet from surface. Labradorite extinctions 19°-19° w4°; 30°-28°w37°; 34°-24°w38°; 31°-23°w23°; 39°-34°w6°-2°. Distance from margin 36.5 meters ± .152.

Grain

Olivine 0.25 mm.
Iron oxide 0.15 mm.
Feldspar 0.56x.024 mm.
Augite (9.1 to 6.5) (or 7.6).

Sp. 15253. Hole 6 at 265 feet from surface. One big anorthite phenocryst (such as are in most exposures found in the Greenstone, yet in every place rare) ex. 43°-43°; regular feldspar; 14°-14°; 28°-30°; 24°-36°; 33°-37°; grain. Distance from margin 28.9 meters ± .152.

Grain coarsest

Olivine .285
Iron oxide 0.24
Feldspar 0.46x0.13
Augite 7 ± (½)

Sp. 15254. Hole 6 at 288 feet from surface. Labradorite extinction angles 25°-27°w9°-4°. Distance from margin 22.1 meters± .152.

Grain

Olivine .33
Iron oxide 0.11

---

[1]Where x is the distance from margin in mm.

Feldspar 0.30x0.07
Augite 5 mm.

Sp. 15255. Hole 6 at 309 feet from surface. Feldspar extinctions 20°-23°-½. Distance from margin 15.9 meters± .152.

Grain
Olivine .30
Feldspar 0.39x0.06 mm.
Augite 4 mm.

Sp. 15256. Hole 6 at 338 feet from surface. Distance from margin 7.35 meters ± .152.

Grain
Olivine .175
Iron oxide 0.12
Feldspar 0.38x0.04
Augite 2.5 mm.

Sp. 15257. Hole 6 at 362 feet from surface. Distance from margin .296 meters ± 0.152.

Grain
Iron oxide 0.08
Feldspar 0.19x0.03
Augite 1.25 mm.

Sp. 15258. Hole 6 at 363 feet from surface. Margin 363.

363-386; (Ss. 15259-66). Allouez CONGLOMERATE Marvine's 15; (22) (701)

at the top a fine grained "ashbed", with a vesicular texture that appears to be due to contact with the overlying Greenstone; below 374 ft. a more ordinary conglomerate, with acid pebbles of quartz porphyrites and felsites. There are also basic pebbles in it and the cement is calcareous. This must, according to our correlation, be the Allouez conglomerate, or the "slide" conglomerate, No. 15 of Marvine's plate, the most important datum plane referred to in most of the sections.

Base below base of the Mesnard (295).

Sp. 15259. Hole 6 at 364 feet from surface. Very amygdaloidal; chloritic; glassy microlitic; vesicular. Probably preliminary gush of this great flow above, or did not the great flow above heat up the preliminary aqueous or muddy matter, causing the formation of numerous steam bubbles?

Sp. 15260. Hole 6 at 372 feet from surface. Fine grained ash particles of altered glass.

Sp. 15261. Hole 6 at 374 feet from surface. Ash fragments and pumiceous fragments showing numerous small vesicles; not many conchoidal glass fragments.

Sp. 15262. Hole 6 at 377 feet from surface. Fragmental, with calcareous cement.

Sp. 15263. Hole 6 at 378 feet from surface. Fragmental, with calcareous cement and porphyrite pebbles.

Sp. 15264. Hole 6 at 379 feet from surface. Pebble in which there is a hypidiomorphic quartz feldspar ground upon which are sharp phenocrysts of acid oligoclase; along here the bed is very conglomeritic.

Sp. 15265. Hole 6 at 380 feet from surface. A pebble with microlitic ground mass and *plagioclase phenocrysts very distinct.*

Sp. 15266. Hole 6 at 386 feet from surface. Underlying trap? shows sharp brotocrysts of orthoclase? and oligoclase on a brown glass?

Sp. 15267. Hole 6 at 389 feet from surface. Fragments of porphyrite and quartz porphyry; microlitic ground mass changed to poikilitic; the line is not sharp; quite possibly there is some displacement of specimens or an erosion contact.

Grain

Iron oxide 6x4

Feldspar 10x2; 7x2; 20x2, av. .37x.06

Augite 0.

386-394; (Ss. 15268-9). MELAPHYRE. This is a fine grained (8) (8) trap with no amygdaloidal top. It is somewhat porphyritic, but tends to be ophitic at the center.

Sp. 15268. Hole 6 at 393 feet from surface. Poikilitic augite; feldspar ex. 25°-28°w-17°.

Grain

Feldspar 10x1; 9x1.5; 11x1, av. .30x.03 mm.

Augite 25x25; 48x23; 30x20, av. 1.03x.68 mm.

Sp. 15269. Hole 6 at 394 feet from surface. Much decomposed; rather fine grained; slightly microlitic like 15222; calcite and chlorite interstices.

Grain

Olivine 6; 7; 10

Feldspar 13x3; 18x4; 10x2, av. .41x.09 mm.

394-448; (Ss. 15269-72). PORPHYRITE, amygdaloidal; more (53) (61) or less amygdaloidal for 21 feet at the top and 12 feet at the bottom. This is really of the intermediate type with a doleritic texture in the middle.

Sp. 15270. Hole 6 at 405 feet from surface. Low angled feldspar? Feldspar very abundant. Ex. 12°-15°w-32°. Margin at 448 ft.

Grain

Olivine 12; 12; 12

Feldspar 30x3; 35x6; 26x5, av. .91x.14 mm.

Augite 25x12; 30x16; 20x16, av. .75x.44 mm.

Sp. 15271. Hole 6 at 415 feet from surface. Poikilitic augite feldspar laths, ex. 20°-24°w-40°, 28°-38°; 27°-28°; 23°-30°.

Grain

Olivine 10; 12; 15

Feldspar 20x3; 23x3; 24x4, av. .67x.10 mm.

Augite 75x56; 55x40; 60x50, av. 1.90x1.46 mm.

Sp. 15272. Hole 6 at 429 feet from surface. Very feldspathic; low angled feldspar? much altered olivine; augite all gone.

Grain

Olivine 6; 7; 9

Feldspar 23x2½; 18x2; 26x7, av. .67x.11 mm.

448-512; (Ss. 15273-7). MELAPHYRE, ophite; not a very (62) (123) pronounced type; about 8 feet amygdaloidal with calcite veins; feldspathic: slight mottling. At this bed we probably pass over to the record of hole No. II.

Sp. 15273. This may be 15373. Hole 6 at 456 feet from surface. Marked porphyritic; low angled feldspar; little augite; microlitic ground.

Grain

Feldspar phenocrysts 57x43; 40x24; 30x23, av. 1.27x.90 mm.

Augite 2; 1; 1; 2; 3; 6; 5.

Sp. 15274. Hole 6 at 470 feet from surface. The feldspar between the augite patches is generally larger than that enclosed in them.; very poikilitic; labradorite ex.-37°w26°-17°; -13°w-28°; -36°w44°-43°; -11°w27°-37°; -14°w36°-38°. This appears to be an augite porphyrite.

Grain

Olivine 20; 30; 14

Feldspar 43x14; 56x7; 38x14, av. 1.37x.35 mm.

Augite 120x120; 80x80; 75x55, av. 2.75x2.55 mm.

Sp. 15275. Hole 6 at 478 feet from surface. Very coarse feldspar; augite idiomorphic in octagonal long prisms. There are also clouded interstices and an amygdule with laumontite? Feldspar ex. 18-18°; -4°w28°-31°.

Grain

Iron oxide 40x20; 30x25; 44x10, av. 1.14x.55 mm.

Feldspar 72x9; 43x9; 38x34, av. 1.53x.52 mm.

Augite 72x16; 50x7; 40x8, av. 1.62x.31 mm.

Sp. 15276. Hole 6 at 510 feet from surface. Labradorite extinction 24°-28°; 35°-27°w18°-; 20°-30°w42°-34°; 53°.

Grain

. Olivine 9; 23x22; 20x10

Feldspar 45x4; 17x2; 20x2, av. .82x.08 mm.

Augite 16x15; 24x20; 23x10, av. .63x.45 mm.

Sp. 15277. Hole 6 at 512 feet from surface. Contact of porphyritic, glassy amygdaloids with underlying ash; the red, compact side is the bottom I presume. Distance from margin 0 feet.

Grain

Feldspar phenocryst 16x2; 11x3; 21x4, av. .48x.09.

The red bottom amygdaloid shows much of a red glass (decomposed, more or less polarizing) with numerous sharp porphyritic crystals running out into a fringe of feldspar trichites. There are numerous small vesicles lined with iron oxide. Trichites about 0.1 wide, 4 to 5 long at times. The rest is an amygdaloidal ash sediment (fragments and plates of iron oxide very common), with a number of amygdules filled with zeolites.

DRILL HOLE No. II.

As no conglomerate appears in drill hole No. II, its top bed, an ophite, must find its correlate at or below No. VI, 386 feet. Hence No. II must find for its first belt of amygdaloid, which occurs from 57 feet to 58 feet, a match in No. VI, not above 450 feet. The first such match is at No. VI, 512 feet, which we have adopted, since that will give us in each drill hole a heavy ophite above and a smaller one below. If we compute the dip from this correlation we find a dip, (12° 10′), nearly a degree flatter than the last computation. If the dip were the same as previously or even steeper, drill hole No. II, 0 feet, would find its correlate at No. VI, 489 feet, or lower, but to say nothing of the fact that the beds in this case would not match as well, observations at the surface show that No. II is close to the top of the Greenstone, or "backbone" ridge and cannot be very much below the great ophite, No. VI, 124-363 feet, which forms it. This of course favors as high a correlation in No. VI as we can get. The extra flat dip might be due to a fault throwing No. VI up, but whether the fault strikes with the strike of the beds, and produces the ridge on which No. VI stands, or runs north, throwing the east side to the south, as analogy would render likely, or runs to the east, throwing the south side up and to the west, is not certain. It might pass through No. VI, near 393 feet. The upthrow, if 13° is the true dip, would be 34 feet only.

2. 0-57; (Ss. 15067-9). Melaphyre, ophite; rather feldspathic; 6. 448-512; in the exposures around the drill holes there are agate and laumontite amygdules.

Sp. 15067. Hole 2 at 2 feet from surface. Poikilitic augite; labradorite; olivine

small, changed to *talc;* apatite needles; much iron oxide; feldspar ex. 21°-19°; 14°-11°w42°; 30°-32°w23°.

Grain

Olivine 6x6; 4; 4

Augite 100x95; 90x50; 160x40, av. 3.50x1.85.

Sp. 15068. Hole 2 at 24 feet from surface. Similar to 15067.

Grain

Olivine 6; 4

Augite 130x120; 120x100; 130x80, av. 3.80x3.00 mm.

Sp. 15069. Hole 2 at 56 feet from surface. Drusic; similar; contact possibly here.

Grain

Olivine 4; 5; 8; 4; 11; 7

Feldspar 22x4; 22x2; 22x3, av. .66x.09 mm.

Augite 36x32; 48x30; 60x40, av. 1.44x1.02 mm.

57-64; (Ss. 15070-1). MELAPHYRE; fine grained, but of (7) (123)/(130) ophite type, equivalent to No. VI, 512-523 feet, which may be more than one flow.

Sp. 15070. Hole 2 at 58 feet from surface. Thoroughly decomposed; amygdaloid a little finer grained. Margin at 57 ft.

Grain

Olivine pseudomorphs 4; 2; 5

Feldspar 18x3; 19x3; 23x3, av. .60x.09.

Sp. 15071. Hole 2 at 63 feet from surface. About same grain as 15067; same type. Distance from margin 64.

Grain

Olivine 6; 7; 6

Feldspar 22x2; 20x2; 21x2.5, av. .63x.06 mm.

Augite 16x14; 14x14; 24x8, av. .54x.36 mm.

64-136; (Ss. 15072-5). MELAPHYRE, Mandan (?) ophite. (70) (200)

Sp. 15702. Hole 2 at 78 feet from surface.

Grain

Olivine 14; 19; 18

Feldspar 22x1.5; 17x2; 20x4, av. .59x.07 mm.

Augite 60x40; 50x40; 70x40, av. 1.80x1.20 mm.

Sp. 15073. Hole 2 at 100 feet from surface. Poikilitic; similar to 15068.

Grain

Olivine 14; 9; 10

Feldspar 35x6; 24x4; 28x3, av. .87x.13 mm.

Augite 110x100; 110x90; 126x110, av. 3.46x3.00 mm.

Sp. 15074. Hole 2 at 133 feet from surface. Drusic and, as usual, chloritic.

Grain

Olivine 8; 10; 18x14

Feldspar 17x3; 23x5; 23x3, av. .63x.11 mm.

Augite 116x82; 100x86; 116x80, av. 3.32x2.48 mm.

Sp. 15075. Hole 2 at 136 feet from surface. Fine grained sediment in contact with much altered microlitic porphyrite; augite in granules. Section is of the base probably. The minute feldspar phenocrysts have microlitic trichitic forked additions. The sediment contains fragments of augite and porphyrite. At margin 136.

Grain

Feldspar 12x1; 15x2; 16x3, av. .43x.06.

136; (S. 15075). SEDIMENTARY seam.

136-175; (Ss. 15075-9). HOUGHTON CONGLOMERATE Marvine's 14? (38) (238)

The samples of this bed were but scant as it is described as very rotten, and much of it was lost. At 167 feet a clay seam was noted. The samples are not sufficient to determine surely whether we are dealing with an amygdaloid full of sandstone seams, or with a fault, or with a scoriaceous conglomerate. But this is the proper place for the Houghton conglomerate.

Sp. 15076. Hole 2 at 138 feet from surface. Basic sediment with microlitic porphyrite.

Sp. 15077. Hole 2 at 164 feet from surface. Very feldspathic; contact of fine grained amygdaloidal microlitic porphyrite with fine grained sedimentary tufa.

Grain

Olivine 15x11; 12x10; 10x8, av. .37x.29

Feldspar 5x1; 5x1; 8x2, av. .18x.04

Augite 1; 1; 1; 2; 3; 7.

Sp. 15078. Hole 2 at 167 feet from surface. Fine grained amygdaloid; very sharp olivine.

Grain

Olivine 13x12; 14x9; 9x9, av. .36x.30

Feldspar phenocrysts 30x15; microlites 8x1; 8x1; 7x1, av. .23x.03.

Sp. 15079. Hole 2 at 175 feet from surface. Sediment (in contact with fine grained amygdaloid) with fragments like 15078.

There is a very notable thinning in the distance from base of Allouez to base of Houghton Conglomerate, i. e. (238) as compared with the Central Mine section (p. 264) (640 to 685), but this is somewhat similar to the shrinking in the Greenstone itself.

175-214; (Ss. 15080-2). MELAPHYRE, ophite. There is some (38) (38)

doubt whether this is not one flow with the underlying.

Sp 15080. Hole 2 at 177 feet from surface. Fine grained poikilitic amygdaloid; some olivine green and black; also in little grains; also chloritic spots.

Grain

Olivine 16; 12; 9

Augite 14x13; 15x12; 20x12, av. .49x.37.

Sp. 15081. Hole 2 at 210 feet from surface. Poikilitic.

Grain

Iron oxide 5; 6; 5

Feldspar 17x3; 12x3; 16x3, av. .45x.09 mm.

Augite 47x35; 50x33; 33x30, av. 1.30x.98 mm.

Sp. 15082. Hole 2 at 214 feet from surface. Fine grained amygdaloid; phenocrysts of olivine. Margin at 214 feet.

Grain

Olivine 4x2; phenocryst 20x26; 13x12, av. .55x.63

Feldspar 11x1.5; 9x1; 12x1, av. .32x.17.

Augite 1 or 2?

From base of Houghton Conglomerate (38)

214-271; (Ss. 15083-5). MELAPHYRE, ophite; about 9 feet coarsely (56) (94)

amygdaloidal at the top, and 1 foot at the bottom.

Sp. 15083. Hole 2 at 263 feet from surface. Poikilitic; the olivine turns to dark

red, and finally becomes opaque like iron oxide,—the bowlingite type of alteration. The feldspar enclosed in the augite patches are smaller than that between them.

Grain

Olivine 10; 15x18; 3

Feldspar 30x6; 26x3; 22x7; 35x7; 23x3, av. .90x.17

Augite 29x20; 63x44; 45x40, av. 1.37x1.04.

Sp. 15084. Hole 2 at 270 feet from surface. Fine grained poikilitic.

Grain

Olivine 15x13; 12; 5

Feldspar 12x2; 13x2; 16x3, av. .41x.07 mm.

Augite 30x20; 30x15; 30x15, av. .90x.50 mm.

Sp. 15085. Hole 2 at 271 feet from surface. Amygdaloid fine grained, *marked* altered yellow red olivine; feldspar seriate and tending to run into microlites near margin at 271.

Grain

Olivine phenocrysts 17x13; 22x20; 27x20, av. .66x.53 mm.

Feldspar 21x12

Augite 2-5?

271-325; (Ss. 15086-7). MELAPHYRE, ophite; about 14 feet of (53) (147)

amygdaloid at top; at 315 feet and 320 feet, seams of decomposition, and then more amygdaloidal to bottom; carries laumontite and calcite.

Sp. 15086. Hole 2 at 296 feet from surface. Poikilitic; altered olivine as in the bed above; polysomatic augite mottlings.

Grain

Olivine phenocryst 17; 2; 3 etc.

Feldspar 10x1; 16x7; 14x4; 23x3, av. .52x.12 mm.

Augite polysomatic aggregate 55x50; 45x45; 53x32, av. 1.53x1.27 mm.

325-365; (Ss. 15087-8). AMYGDALOIDS; probably more flows than one; base ill-defined.

Sp. 15087. Hole 2 at 325 feet from surface. Laumontite; amygdaloid; olivine as in sections above; amygdules not so fine as usual in contacts; this and the fact that the parting is not marked may be due to the fact that this and the overlying are immediately following gushes. At margin 325.

Grain

Olivine 18x10

Feldspar 18x4 and less

Augite 0.

Sp. 15088. Hole 2 at 340 feet from surface. Fine grained with altered olivine and small amygdules.

Grain

Olivine 10x8; 20x13; 11x10, av. .41x.31

Iron oxide 2; 2; 2 like small olivine

Feldspar ? 10x2? all altered

Augite 5; 5; 4; 7; 5; 7.

365-438; (Ss. 15089-91). MELAPHYRE, ophite; amygdaloidal at (71) (218)

top, grey, and apparently not very basic.

Sp. 15089. Hole 2 at 411 feet from surface. Poikilitic; olivine altered green to black.

Grain

Olivine 18x15; 13x10; 18x11, av. .49x.36

Feldspar 20x3; 33x3; 21x4, av. .74x.10

Augite 25x15; 20x18; 40x20, av. .85x.53.

The grain of the augite is illustrated by points q of Fig. 16 (of the Isle Royale Report).

Sp. 15090. Hole 2 at 426 feet from surface. Basic feldspar; poikilitic amygdaloid; chloritic interstices; olivine not so plain, iron oxide instead.

Grain

Olivine 4; 7; 8; 7

Feldspar 20x7; 13x7; 17x4 (somewhat larger than the average) av. .60x.18

Augite 140x100; 70x60; 80x70, av. 2.90x2.30 mm.

Sp. 15091. Hole 2 at 434 feet from surface. Similar; rather finer grained; olivine is once more conspicuous.

Grain

Olivine 12x10; 15x15; 15x14, av. .42x.39 mm.

Feldspar 22x4; 15x5; 22x4, av. .59x.13 mm.

Augite 55x30; 30x25; 45x30, av. 1.30x.85 mm.

438-475; (Ss. 15092-4). AMYGDALOIDS, brecciated; very soft, so (36) (254) that we have only 17 feet of core for 38 feet of boring, probably a number of beds and possibly a fault. (Houghton conglomerate?).

Sp. 15092. Hole 2 at 438 feet from surface. Marginal microlitic porphyritic amygdaloid for a way; feldspar low angled and the phenocrysts run out into trichites. This is the first below the Greenstone to look like the Tobin or melaphyre porphyrite type.

Grain

Feldspar phenocrysts 17x3; 10x2; 20x10, av. .47x.15; microlites 6x.1; 5x1, av. .18x.01.

Sp. 15093. Hole 2 at about 450 feet from surface. Brecciated fine grained contact; it might be a fault breccia or fragments.

Sp. 15094. Hole 2 at about 460 feet from surface. Brecciated microlitic; fine grained; decomposed; similar to 15093.

Grain

Feldspar 25x9 and less.

475-556; (Ss. 15095-7). MELAPHYRE, ophite; top and bottom (79) (333) quite uncertain, but the massive mottled center is quite distinct; at about 554 feet becomes much veined, disintegrated, and prehnitic, with some *copper*.

Sp. 15095. Hole 2 at 476 feet from surface. Poikilitic amygdaloid; much altered olivine. Margin at 475.

Grain

Olivine 12; 8; 9

Feldspar 20x3; 20x3.3; 15x3, av. .55x.09

Augite 43x35; 44x25; 35x30, av. 1.22x.90.

Sp. 15096. Hole 2 at 516 feet from surface. Poikilitic amygdaloid; with green altered olivine; chloritic interstices.

Grain

Olivine 6; 10; 10x10

Feldspar 36x10; 22x4; 17x4, av. .75x.18 mm.

Augite 60x53; 80x80; 55x43, av. 1.95x1.76 mm.

Sp. 15097. Hole 2 at 554 feet from surface. Fine grained microlitic, porphyritic, originally, but now all poikilitic quartz patches.

Grain

Feldspar phenocrysts pseudomorphs 13x2; 23x4; 20x9.

556-570; (Ss. 15098-9). AMYGDALOID, brecciated. (14) (347)

Sp. 15098. Hole 2 at 561 feet from surface. Brecciated; olivine marked; microlitic; melaphyre.

Grain

Feldspar seriate, from 20x3 to 3x.1

Augite 0.

Sp. 15099. Hole 2 at 570 feet from surface. Microlitic porphyritic. At margin 570.

Grain

Olivine 2; 3; 3

Feldspar 33x5; 15x4 and smaller

Augite 0.

570-600 (?). MELAPHYRE, ophite (?); amygdaloidal; core about half ground away. (29) (376)

600-631; (Ss. 15100-1). MELAPHYRE, ophite. (30) (406)

Sp. 15100. Coarse grained olivinitic, somewhat porphyritic; no augite? much decomposed.

Grain

Olivine 15; 20; 4; 4; 5

Feldspar 20x4; 33x5; 27x4, av. .80x.13.

Sp. 15101. Hole 2 at 624 feet from surface. Poikilitic; ophite; melaphyre.

Grain

Olivine phenocrysts 22; 17; 18

Feldspar 12x6; 11x3; 16x5, av. .39x.14

Augite 1-2 mm. to the naked eye; 50x30; 46x25, av. 1.60x.91.

631-650+; (S. 15102). AMYGDALOID; at 650 feet very much ground away and decomposed; a chance for a slide. (71) (477)

Below this point No. II shows a massive, dictinctly mottled ophite, all the way down (chlorite vein from 697 feet down to 700 feet), so coarse at the bottom that it is evidently considerably thicker, upwards of 70 feet thick. If this is repeated above, it must be either at 64 feet (the beds above 64 feet are too massive) or at 365 feet, which is possible, though there are reasons brought out by the microscope for believing this also not to be the case; moreover, the beds above do not harmonize. While there are several disturbed zones in No. II, there is no pressing reason, microscopic or otherwise, for supposing that a repetition in the series is shown.

When we turn to drill hole No. IV, we find a similar melaphyre at the very top If we let No. II, 683 feet, be equivalent to No. IV, 0 feet (using the similar grain of the rock as an indication that the two samples have similar positions in the flow), we have for the dip 14° 30′. Thus, either the dip has become steeper or the correlation should be higher up in hole No. II, or a fault separates No. II and No. IV such that No. IV is thrown up. This last supposition I deem most likely, for there is a ravine just to the east of No. IV, through which such a fault, running north and south, might go. Moreover, tunnels No. II and III do not strike the same rock, as would otherwise be expected; the one is east and the other west of this supposed break. Drill holes Nos. V and II are about in the direction of dip from each other and the fault suggested would also throw up No. IV relative to No. V, which is what the topography and records suggest.

Tunnel No. VII is in ophite, with seams, red, white, clayey and chloritic, which

may be matched anywhere along the middle of hole No. II and do not throw much light on the correlations. Supposing the dip to be 13°, as it has been taken to be to the south, the corresponding up-throw of No. IV would be 52 feet.

Sp. 15102. Hole 2 at 639 feet from surface. Similar to 15101; fine grained. Distance from margin 650?

Grain

Olivine phenocryst 20x14; and small
Feldspar 70x3; 13x2; 20x1; 23x5, av. 1.05x.09
Augite 12x5; 20x15; 25x13, av. .57x.33.

From 2-4, 650 feet (Ss. 15103-A)

Sp. 15103. Hole 2 at 655 feet from surface. Much red olivine; very fine grained.

Grain

Olivine phenocryst 25; second generation 3; 5; 3; 5; 4; 3, av. 0.12 mm.
Feldspar 8x1; 13x3; 12x3, av. .33x.07 mm.

Sp. 15104A. Hole 2 at 683 feet from surface. Coarse grained poikilitic.

Grain

Olivine 9; 12; 10
Feldspar 30x4; 23x4; 15x4, av. .68x.12
Augite 2-3 mm. or 3.5 mm.; 145x100; 100x70; 110x90; 90x90, av. 3.55x2.60.

(477)

DRILL HOLE No. IV

4. 0-40 feet (Ss. 15155-7). MELAPHYRE, ophite.

Sp. 15155. Hole 4 at 0 feet from surface, appears a little coarser than 15104A, if anything. Altered, more green olivine.

Grain

Olivine phenocrysts 17; 17; 7 also some smaller grains
Feldspar 18x5; 12x2; 14x5, av. .44x.12 mm.
Augite 2-3 mm., 75x50; 120x70; 120x80, av. 3.15x2.00 mm.

Sp. 15156. Hole 4 at 36 feet from surface. Somewhat finer grained than 15156.

Grain

Olivine phenocryst 17x10; second generation 3; 6
Feldspar 14x3; 23x5; 23x3, av. .60x.11
Augite 80x63; 105x43; 80x70 (about 2 mm.).

Sp. 15157. Hole 4 at 40 feet from surface. Very fine grained with microlites of feldspar from the size measured below to smaller.

Grain

Feldspar 13x2; 15x3; 19x3, av. .47x.08 mm.
Augite ?

(477)

40-108; (Ss. 15158-60). MELAPHYRE, ophite; about 9 feet of (66) (543)

Amygdaloid at top, with calcite and chlorite—

Sp. 15158. Hole 4 at 51 feet from surface. Distinctly poikilitic, but the augite is long in clinopinacoidal sections, showing that it is not entirely without crystal form.

Grain

Olivine 4; 5; 7; 13; 6; 7
Feldspar 13x2; 13x2; 20x2, av. .46x.06
Augite 1 mm.?; 45x40; 45x30; 80x25, av. 1.7x0.95.

The grain of the augite is plotted as p in Fig. 16 of the Isle Royale Report, Vol. VI.

Sp. 15159. Hole 4 at 68 feet from surface. Coarser than 15158.

Grain

Olivine 5; 5; 7; 7; 5; 10

Feldspar 13x2; 11x1; 18x1, av. .42x.04 mm.

Augite 2-3 mm.; 63x55; 55x40; 160x65; 115x65, av. 3.27x1.88 mm.

Sp. 15160. Hole 14 at 100 feet from surface. Olivine red with iron oxide, the bowlingite alteration.

Grain

Iron oxide 7; 5; 8; 8; 7; 8, av. .21 mm.

Feldspar 13x2; 10x2; 12x15, av. .35x.19

Augite 1-2 mm.; 50x45; 85x30; 65x30, av. 2.00x1.05.

108; (S. 15161). SEDIMENT, basic; to the naked eye like (543) a fine grained amygdaloid. Evidently connected with the sediment just below.

Sp. 15161. Hole 4 at 108 feet from surface. This may be partly ash but mainly real sediment of basic material such as labradorite sand, etc.

108-133; (Ss. 15162-3). MELAPHYRE, ophite; fine grained; 24 (567) at 122 feet, fissure with quartz crystals.

Sp. 15162. Hole 4 at 110 feet from surface. 2 large phenocrysts of feldspar apparently orthoclase !; poikilitic texture just beginning; low angled feldspar.

Grain

Olivine 5; 4; 5; 3; 4; 5

Iron oxide 5x.2; 2; 4; 11x0.3; 2

Feldspar phenocrysts 115x60; second crop 14x2; 12x2; 13x2, av. .39x.06.

Augite 4x2; 5x4; 4x4, av. .13x.10.

Sp. 15163. Hole 4 at 126 feet from surface. Very chloritic; poikilitic also with large phenocrysts of feldspar. Magnetite and hematite occur.

Grain

Iron oxide 3; 4; 4; 10x.5

Feldspar first generation 47x42; 120x35; second crop (ex. 10°) 205x24 (ex. 18°.0) 15x3; 12x2; 12x2, av. .39x.07

Augite 40x30; 40x20; 40x30; av. 1.20x.80. See Fig. 16 of the Isle Royale Report, Vol. VI, the grain plotted as 0.

133-135; (Ss. 15164). SANDSTONE, basic; the CALUMET CONGLOMERATE (569) (No. 13 of Marvine's table, opp. p. 60) should come about here. In the Central Mine (see p. 267), the Calumet is about 815 feet below the Houghton and 1500 ft. below the Allouez. This is not quite as much shrinkage as before. As the top of the bed below does not begin in an amygdaloidal streak, but is quite coarse, we must infer an erosion or a slide at this point.

Sp. 15164. Hole 4 at 133 feet from surface. Fine grained basic conglomerate; decomposed large phenocrysts of feldspar; the general impression of all these rocks is that the iron oxide is produced in resorption or decomposition of the olivine.

Grain

Olivine 11x6

Feldspar 20x2; 90x17, av. 1.83x.31.

135-227; (Ss. 15165-8). MELAPHYRE, ophite; very ferruginous. (90) (90)

Sp. 15165. Hole 4 at 135 feet from surface. Beginning to be poikilitic; red olivine; one big amygdule; feldspar ex. 23°-3°w14°-3°; this does not seem like the extreme margin of flow and one would say there was probably erosion here.

Grain

Olivine 8; 14; 10; 7; 10; 7

Feldspar 20x5; 26x5; 20x3, av. .55x.13
Augite 32x30; 60x17; 38x23, av. 1.30x.70
The augite grain is given as n in Fig. 16 of Vol. VI, Part I.

Sp. 15166. Hole 4 at 175 feet from surface. Poikilitic; unusually much iron; basic feldspar has higher birefringence. Ex. 60°; 60°; 35°-7°w40°-29°; 28°-5°w 55°-32°.

Grain
Olivine 18; 7; 10; 5; 10; 10
Augite to the naked eye 3-4 mm.; 100x70; 100x40; 80x70, av. 2.80x1.80.

Sp. 15167. Hole 4 at 225 feet from surface. Fine grained microlitic porphyrite; altered olivine; feldspar low angled.

Grain
Olivine 15; 13; 16
Iron oxide 4; 4; 4; 4; 4; 5
Feldspar (1) 15x3; 32x7; (2) 13x3; 12x3; 15x5
Augite 10x8; 25x12; 16x11, av. .51x.31 mm.

227-245; (Ss. 15168-9). AMYGDALOID, brecciated. (18) (108)

Sp. 15168. Hole 4 at 227 feet from surface. Contact of two flows; one has much more iron, and appears to be the lower since fragments of it are enclosed in the upper.

Grain
Olivine pseudomorphs perhaps 7? 4?
Iron oxide (much) dust.
Feldspar 11x2; 13x2; 17x2; 11x6, av. .43x.10 mm.
Augite 0.

Sp. 15169. Hole 4 at 245 feet from surface. Like the lower part of 15168; fragments of microlitic melaphyres with coarse calcareous cement; more or less iron oxide in the fragments.

Grain
Olivine 4; 5; 6; 7; 5; 14.

245-263; (Ss. 15170-1). AMYGDALOID. (18) (126)

Sp. 15170. Hole 4 at 262 feet from surface. One large phenocryst of olivine altered. See Fig. 16.

Grain
Olivine 11; 7; 4; 5; 9; 16
Feldspar 19x3; 14x4; 25x4, av. .58x.11 mm.
Augite 4x3; 6x3; 10x7, av. .20x.13 mm.

Sp. 15171. Hole 4 at 263 feet from surface. Well marked altered olivine.

Grain
Olivine 10; 6; 10; 15; 10; 9, av. 0.30 mm.
Iron oxide 12; 2; 2; 4, av. 0.11 mm.
Feldspar 22x5; 15x5; 10x7, av. .47x.17 mm.
Augite 2; 1; 2; 3; 5; 1, av. .07 mm.

263-280; (S. 15172). AMYGDALOID. (17) (143)

Sp. 15172. Hole 4 at 280 feet from surface. Same; well marked amygdaloid; feldspar smaller as well as of the size measured.

Grain
Olivine 12x10
Feldspar 35x7; 22x5; 22x5, av. .79x.17 mm.

280-304; (Ss. 15173). AMYGDALOID. (23) (166)

The above series of four amygdaloids are very much alike, very soft, veined, red, and so much ground away that only about half the core was left; consequently the limits of the various flows are very uncertain. Prehnite also occurs in them. This may be not far from the horizon of the Osceola and Calumet amygdaloids.

Sp. 15173. Hole 4 at 303 feet from surface. Very fine grained marginal amygdaloid?; feldspar often microlitic decomposed.

Grain

Feldspar phenocrysts 15; 25x5; 8.

304-424; (Ss. 15174-83). MELAPHYRE, ophite (117) (283)

Compare Central Mine belt 35, and the big ophite that comes between the Osceola and Calumet amygdaloids, p. 269.

Clay seam at 313 feet, near which the rock is much decomposed, fissured and seamed.

Sp. 15174. Hole 4 at 305 feet from surface. Much altered; fine grained; full of iron oxide dust.

The grain of the augite is given by points marked 1 in Fig. 16 of the Isle Royale Report, Vol. VI.

Sp. 15175. Hole 4 at 308 feet from surface. Coarser than 15174; reddened altered olivine; very basic feldspar.

Grain

Olivine 10; 15; 8, av. 0.33 mm.

Iron oxide 7; 9; 5, av. 0.21 mm.

Feldspar 30x3; 8x2; 20x3; 10x1, av. .56x.07

Augite 8x12; 7x8; 7x8, av. 0.28x0.23 mm.

Sp. 15176. Hole 4 at 313 feet from surface. Clay which may perfectly well be the fluccan of a slide fault.

Sp. 15177. Hole 4 at 336 feet from surface. Poikilitic; olivine altered to green mica; with strong birefringence; feldspar extinction 8°-6°w29°.

Grain

Olivine 7; 14; 9; 10; 7; 8; 40x40

Feldspar 12x3; 14x13; 12x3; 20x3, av. .48x.18

Augite 1-2 mm.; 39x32; 35x23; 30x30, i. e., av. 1.04x0.83.

Sp. 15178. Hole 4 at 345 feet from surface. Feldspar ex. 18°-3°w51°-18°; 26°-18°w48°-25°.

Grain

Olivine 10; 6; 23; 6; 12; 12

Feldspar 19x6; 19x2; 22x11, av. .60x.19 mm.

Augite 2-3 mm.; 90x80; 115x42; 80x64, av. 2.85x1.86 mm.

Sp. 15179. Hole 4 at 365 feet from surface. Feldspar ex. 20°-0°w49°-35°; 27°-14°w44°-30°.

Grain

Olivine only green 15; 6; 5; 11; 10; 8, av. .27 mm.

Feldspar 20x2; 18x6; 40x6, av. .78x.14 mm.

Augite 2-4 mm.; 110x90; 120x75; 110-95, av. 3.40x2.60 mm.

Sp. 15180. Hole 4 at 395 feet from surface. A vein of decomposition runs through the section. Feldspar ex. 26°-25°w40°-31°.

Grain

Olivine 7; 15; 15; 5; 7; 4

Feldspar 23x5; 23x2; 19x5, av. .65x.12 mm.

Augite 2-3 mm.; 115x65; 80x60; 65x60; av. 2.60x1.85 mm.

Sp. 15181. Hole 4 at 399 feet from surface. Olivine, mica, and iron oxide grown together are abundant.

Grain

Olivine 7; 6; 9; 10; 5; 6, av. 0.21 mm.

Feldspar 16x4; 25x6; 23x5, av. .64x.15 mm.

Augite 1-2 mm.; 60x50; 70x65; 50x45, av. 1.80x1.60 mm.

Sp. 15182. Hole 4 at 420 feet from surface. Poikilitic.

Grain

Olivine 18; 10; 9; 2; 5; 12, av. 0.40x0.16 mm.

Feldspar 12x2; 16x5; 12x4, av. .40x.11 mm.

Augite 1 mm.; 20x16; 15x12; 17x16, av. 0.52x0.44 mm.

Sp. 15183. Hole 4 at 423 feet from surface. Minute poikilitic texture. Distance from margin 1 ft.

Grain

Olivine 8; 10; 3; 15; 10; 8, av. 0.33x0.21 mm.

Augite 8x6; 15x12; 7x6, av. 0.30x0.24 mm.

424-434; (Ss. 15184-6). AMYGDALOID, chloritic and laumontite. (10) (293)

Sp. 15184. Hole 4 at 424 feet from surface. Similar but more feldspathic; contact apparently right in the section, at any rate trichitic. Distance from margin 0.

Grain

Olivine 10x8; 6x5; 6x4, av. 0.22x0.17 mm.

Feldspar 15x4; 16x3; 13x4, av. .44x.11 mm.

Augite 0.

The grain is given by points marked m of Fig. 16 in Vol. VI, Part I.

Sp. 15185. Hole 4 at 431 feet from surface. Quite feldspathic; poikilism faint if present.

Grain

Feldspar 43x4; 24x3; 32x4; 18x3, av. .97x.11 mm.

Augite 42x40; 25x23; 40x36, av. 1.07x.99 mm.

Sp. 15186. Hole 4 at 434 feet from surface. Fine grained microlitic porphyrite; trichitic and the phenocrysts whose dimensions are given have trichitic additions.. Distance from margin 0.

Grain

Olivine 5; 7; 5; 13

Feldspar 15x4; 43x6; 35x6, av. .93x.16 mm.

434-450; (Ss. 15187-8). AMYGDALOID; porphyritic texture, (16) (309) which is common in the other amygdaloids, with *copper*, laumontite and prehnite. Compare Osceola amygdaloid.

Sp. 15187. Hole 4 at 438 feet from surface. Like 15186 but coarser.

Grain

Olivine 7; 5; 7; 6; 3; 7; 6; 15; 5, av. 0.20 mm.

Feldspar 12x2; 30x6; 20x3, av. .62x.11 mm.

Augite 0.

Sp. 15188. Hole 4 at 450 feet from surface. Microlitic porphyritic brecciated. There may be a contact of two flows? Distance from margin 450.

Grain

Olivine 4; 7; 4; 5; 5; 5, av. 0.15 mm.

Feldspar 20x4; 40x7; 30x5, av. .90x.16 mm.

Augite 0.

1. 450-605½; (Ss. 15189-96). MELAPHYRE, ophite; very feld- (152) (461) spathic; the bottom of bed not reached at the end of the hole, but the grain has be-

come finer, indicating that we are close to the foot. With this flow we pass to drill hole No. V, and the latter must overlap unless the dip is 20°, or unless there is a fault of about 150 feet. With a dip of 13° we should expect to find No. V, 0 feet, at No. IV, 436 feet; if the dip is 14°, then at No. IV, 462 feet, etc. But the ophites around the top of No. V are judging either from their thickness as measured in the section, which might be affected by the numerous seams in No. V, or from the coarseness of grain, not as thick as the bottom flow in No. IV. Nor are they quite as feldspathic. The bottom of No. V, though it lies in a fissure, and the record cannot be made out clearly, is in coarse feldspathic ophite, which corresponds both to the bottom of No. IV and also to the top of No. I. Drill hole No. I lies on the northwest side of a ridge which rises from Washington River, and is composed of ophites like the Greenstone. No. I is 30 feet lower than No. IV and 2092 feet+1293 feet, i. e., 3385 feet from it to the northwest, at right angles to the strike. Thus at 14° dip the top of No. I would be (846+30=876) feet below the top of No. IV; at 13° dip (782+30) 812 feet below it. Thus there would be a gap of something over 200 feet between the bottom of No. IV and the top of No. I. But as No. IV ends in a coarse ophite and No. I begins in one, and as field observations show all the intervening rocks to be coarse ophite, and as drill hole No. V is altogether in the same, we may be sure that the apparent intervening gap, if any there be, is composed of ophite. It is doubtful if there be really any such gap. The topography of the Island conforms in general closely to its geological structure, and the thick ophite of the bottom of No. II could hardly fail to make a ridge. The only ridge with which it might be correlated, is directly on the southeast side of No. I. Again, in No. V the only ophite equally coarse is just above 344 feet, and if we assume No. IV, 610 feet, to correspond to No. V, 344 feet, the difference in level in the geological column would be only 128 feet, whereas if the dip is 14°, there should be a difference of level of 324 feet, indicating an up-throw of No. IV of (196 feet) about 200 feet. If the same amount of up-throw existed between No. I and No. IV, the gap in the record between them would be practically wiped away, leaving room for not more than one large ophite flow, which might be the one which occurs at and above the top of No. I and at the bottom of No. V. Since No. V and No. I are 2092 feet apart, at right angles to the strike, and No. V is 108 feet the lower, the top of No. I, with dip=13° would correspond to (483-108) 375 feet, or with dip=14° to (523-108) 415 feet, in No. V, and the two holes would barely overlap. This is probable, as the bottom of No. V and the top of No. I are very similar; so that if not exactly the same horizon, they are probably from the same flow. If we can consider them identical, we can also assume that the top of No. I makes a continuous record with No. IV (No. IV, 606 feet=No. I, 0 feet). This seems on the whole the best plan, as drill hole No. V crosses and recrosses a fissure and there is no guarantee that the different parts of it are in any fixed relation to each other. But at the same time we must remember that in thus allowing about 270 feet of upthrow, we may be shortening our column too much. We may be reasonably confident that the beds we may have thus omitted are two or three large flows of ophite. There are certain reasons which make a fault of the nature we have described probable. The line of strike of such a fault may be marked by the Washington harbor depression. Plate I.

Sp. 15189. Hole 4 at 458 feet from surface. Fine grained poikilitic.

Grain

Olivine 4; 9; 11, av. 0.24 mm.

Feldspar 32x5; 25x5; 22x4; 20x5, av. .82x.15

Augite 30x22; 40x25; 40x23, av. 1.10x.60.

Sp. 15190. Hole 4 at 478 feet from surface.
Grain
Olivine 20x7; 12x10; 10x10; av. 42x.27.
Feldspar 32x6; 30x4; 38x4, av. 1.00x.14
Augite 60x45; 55x40; 60x52, av. 1.75x1.37.

Sp. 15191. Hole 4 at 486 feet from surface.
Grain
Olivine 31x24; 9; 13; 10; 15
Feldspar 25x4; 31x5; 22x5, av. .78x.14
Augite 90x50; 155x90; 110x50, av. 3.55x1.90.

Sp. 15192. Hole 4 at 503 feet from surface. Very feldspathic; drusic; faintly poikilitic; put down with naked eye as coarsest!
Grain
Olivine 12?
Iron oxide 16; 7; 11
Feldspar 40x3; 23x3; 38x4, av. 1.01x.10
Augite 23x20; 50x40?; 50x18, av. 1.23x.78.

Sp. 15193. Hole 4 at 509 feet from surface. Markedly poikilitic, with green olivine; feldspar extinction -15°w42°-35°; 21°-28°.
Grain
Olivine 12x10; 8x14; 15x10, av. .35x.34 mm.
Feldspar 40x3; 37x6; 26x5; 43x8, av. 1.21x.18 mm.
Augite 130x105; 160x100; 130x120, av. 4.20x3.25 mm.

Sp. 15194. Hole 4 at 536 feet from surface. Doleritic interstices; feldspar interstices 17°-22°w56°-35°.
Grain
Olivine 13x13; 9x13; 16x9
Feldspar 25x5; 58x6; 26x3, av. 1.09x.14
Augite 3-4 mm.; 80x65; 160x116; 110x100, av. 3.50x2.81.

Sp. 15195. Hole 4 at 564 feet from surface. Vein.

Sp. 15196. Hole 4 at 595 feet from surface. Note how the chlorite seam winds around the augites and none? of them lie on both sides of it.
Grain
Olivine 24; 15; 15; 15; 10; 12
Feldspar 47x6; 20x3; 34x3, av. 1.01x.12
Augite 63x50; 50x40; 80x40, av. 1.93x1.30.

DRILL HOLE No. V.

We give the record of No. V, though not included in the general section, and owing to the faulting the grain observations are of more importance in indicating displacements than in any other way.

0-104; (Ss. 15197-203). Melaphyre, ophite; veined, decomposed with laumontite; at 18 feet about 2 feet of brecciated vein matter, with white and chloritic seams in the neighboring rock.

Sp. 15197. Hole 5 at 1 foot from surface. Very coarse grain.
Grain
Augite patches 3-4 mm.

Sp. 15198. Hole at 18 feet from surface. Fine grained vein stuff with fragments, augite, etc.

Sp. 15199. Hole 5 at 26 feet from surface. Green and red olivine; poikilitic.

Grain

Olivine 25x13; 10x10; 11x17, av. .46x.34 mm.

Feldspar 27x4; 16x6; 26x5; 23x5, av. .68x.16 mm.

Augite 90x80; 170x80, av. 4.5x2.6 mm.

Sp. 15200. Hole 5 at 50 feet from surface. Finer grained than 15199; green olivine; talc?; poikilitic.

Grain

Olivine 10x7; 14x19; 10x24, av. .44x.50 mm.

Feldspar 13x2; 40x4; 20x3, av. .73x.09 mm.

Augite 70x50; 85x80; 65x60, av. 2.20x1.90 mm.

Sp. 15201. Hole 5 at 64 feet from surface. Green; fine grained drusic; feldspar ex. 16°-43°-32°.

Grain

Olivine 10x10; 15x8; 15x20, av. .40x.38 mm.

Feldspar 45x6; 13x3; 17x3, av. .75x.12 mm.

Augite 2-4 mm.; 85x60; 90x60; 100x100, av. 2.75x2.20 mm.

Sp. 15202. Hole 5 at 100 feet from surface. Green; fine grained drusic; coarse.

Grain

Olivine 15x5; 10x6; 7x7, av. .32x.18 mm.

Feldspar 15x5; 32x4; 34x5, av. .81x.14 mm.

Augite 80x40; 65x50; 60x43, av. 2.05x1.33 mm.

Sp. 15203. Hole 5 at 104 feet from surface. Fine grained poikilitic. Margin at 105+.

Grain

Olivine 8x4; 10x10; 12x8, av. .30x.22 mm.

Augite 43x40; 40x28; 54x40, av. 1.37x1.08 mm.

Sp. 15204. Hole 5 at 105 feet from surface. Very fine grained; *not* microlitic; this appears to be rock like a "slide"; a vein is crossed here as is shown by the sudden change in coarseness, as well as other things.

105; (S. 15205). "Slide" rock, fine grained. Hole 5 at 115 feet from surface. Fine grained poikilitic.

Grain

Olivine 12x11; 13x18; 12x10, av. .37x.39 mm.

Feldspar 16x3; 22x4; 30x8, av. .68x.15 mm.

Augite 1 mm.; 30x27; 28x10; 53x42, av. 1.11x0.79 mm.

130. A similar belt of fluccan to 105.

150-152. Thoroughly decomposed; vein.

188. A thin *fissure;* a red, calcareous, decomposed belt, very prehnitic, possibly also a contact of flows.

105-188; (Ss. 15205-10). MELAPHYRE, ophite; coarsest near 163 feet. (81)

Sp. 15206. Hole 3 at 132 feet from surface.

Grain

Olivine 7x12; 10x7; 16x11, av. .33x.30 mm.

Feldspar 24x5; 23x9; 30x7, av. .77x.21 mm.

Augite 2-3 mm.; 90x60; 150x80; 130x110, av. 3.70x2.50 mm.

Sp. 15207. Hole 5 at 150 feet from surface. Thoroughly decomposed; no perceptible grain, like 15204; full of bodies like those in the Arran pitch? stone; vein material?

Sp. 15208. Hole 5 at 163 feet from surface. Poikilitic.

Grain

Olivine 8x20; 15x10; 10x16, av. .33x.46 mm.

Feldspar 11x4; 25x5; 31x4, av. .67x.13 mm.

Augite 2-3 mm.; 110x100; 80x70; 95x75, av. 2.85x2.45 mm.

Sp. 15209. Hole 5 at 177 feet from surface.

Grain

Feldspar 35x7; 22x3; 22x4, av. .79x.14 mm.

Augite 50x30; 60x40; 40x40, av. 1.50x1.10 mm.

Sp. 15210. Hole 5 at 188 feet from surface. Much decomposed; very prehnitic; about here change in character of flows; less ophitic; more feldspathic.

188-210; (Ss. 15210-3). FELDSPATHIC, ophite; first five feet amygdaloidal; mottling not prominent.

Sp. 15211. Hole 5 at 193 feet from surface. Decomposed fine grained poikilitic.

Sp. 15212. Hole 5 at 196 feet from surface. Slightly coarser.

Sp. 15213. Hole 5 at 210 feet from surface. Sandy vein or clasolite in contact with coarse rock.

210. CLAY seam.

231. Finer grained.

210-343; (Ss. 15214-9). MELAPHYRE, feldspathic ophite. Mottling not prominent, but rather a diabasic texture of feldspar laths; occasional amygdules, seams and veins; toward the bottom the mottling becomes more marked.

Sp. 15214. Hole 5 at 214 feet from surface. Poikilitic; with 2 mm. augite.

Sp. 15215. Hole 5 at 231 feet from surface.

Grain

Augite 1-2 mm.

Sp. 15216. Hole 5 at 231 feet from surface.

Grain

Augite 2-3 mm.

Sp. 15218. Hole 5 at 285 feet from surface. Poikilitic; olivine present. Augite 5-6 mm. patches.

Sp. 15219. Hole 5 at 333 feet from surface. Poikilitic.

Grain

Augite 2-3 mm.

343. Enter *fissure*; rock much decomposed, fine grained and prehnitic.

344. CLAY seam.

346; (Ss. 15220). Feldspathic AMYGDALOID, not far from contact.

365. "Leave fissure," i. e., the amygdaloidal zone?

344-376. Perhaps one small MELAPHYRE, ophite.

375. "Cross fissure" (?).

Sp. 15221 at 367 feet is a pretty feldspathic ophite with 1 mm. augite.

376-415. MELAPHYRE, ophite; amygdaloidal at top. (38)

Sp. 15222 at 376 feet is an amygdaloid; the top of a heavy bed at the lower end of the hole.

Sp. 15223 at 377 feet is quite decomposed.

15224 at 391 feet is very feldspathic and rather even.

397. Cross fissure again (?).

15225 at 410 feet is also quite feldspathic and distinctly poikilitic.

Grain

Olivine 10x10; 15x15; 12x6, av. .37x.31

Feldspar 15x5; 17x6; 32x7, av. .64x.18

Augite 63x35; 110x20; 40x40, av. 2.13x.95.

DRILL HOLE No. I.

Hereafter, in reducing from VERTICAL depth along drill hole to THICKNESS, 1/30 is taken off.

No. I, 0 feet is taken as equivalent to No. IV, 606 feet. This corresponds very nearly to a dip of 14° 20′ which is what we have by correlation of No. I and No. III.

(461)
0-63; (Ss. 15001-4). MELAPHYRE, ophite; mottled, feldspathic, (61) (522)

and slightly amygdaloidal.

Sp. 15001. Hole 1 at 8 feet from surface. Slightly poikilitic, but feldspathic like the beds at the bottom of Hole V.

Sp. 15002. Hole 1 at 25 feet from surface. Similar to 15001.

Sp. 15003. Hole 1 at 50 feet from surface. More poikilitic, but also quite feldspathic.

Sp. 15004. Hole 1 at 6 feet from surface. Distance from margin 63. Not so poikilitic; sedimentary contact.

63-153; (Ss. 15005-10). MELAPHYRE, ophite; amygdaloidal (87) (609)

at top; darker, black, and mottled at bottom. *Copper* and prehnite seams and spangles of *copper* on chloritic joints. In this bed appear the first signs of copper which continue at intervals down to 302 feet.

Sp. 15005. Hole 1 at 87 feet from surface. Contact of amygdaloid and sand.

Sp. 15006. Hole 5. Much feldspar like previous sections, with augite wedged in between.

Sp. 15007. Distinctly poikilitic with 3 mm. augite patches.

Sp. 15008. Hole 1 at 113 feet from surface has an interesting illustration of a big amygdule around which the coarser feldspar becomes porphyritic and interstitial glass and iron oxides appear, largely hematite.

Sp. 15009. Hole 1 at 138 feet from surface. Poikilitic with 3 mm. patches of augite.

Sp. 15010. Hole 1 at 148 feet from surface. Fine grained microlitic; porphyritic; amygdaloidal.

(609)
153-227; (Ss. 15011-6). MELAPHYRE, ophite; amygdaloidal (76) (681)

for the first 10 feet, which character fades out in the next 9 feet; chlorite and calcite amygdules and veins.

Sp. 15011. Hole 1 at 153 feet from surface. Fine grained, microlitic porphyritic amygdaloid, very black with iron oxides.

Sp. 15012. Hole 1 at 158 feet from surface. Coarser, not so porphyritic.

Sp. 15013. Hole 1 at 174 feet from surface. Slightly poikilitic with 1 mm. augite patches.

Sp. 15014. Hole 1 at 197 feet from surface (sections misnumbered).

Sp. 15015. Hole 1 at 213 feet from surface. Fairly coarse, showing a vein.

Sp. 15016. Hole 1 at 226 feet from surface. Fine grained poikilitic.

227-275; (Ss. 15017-20). MELAPHYRE, ophite; 5 feet of amygdaloid (46) (727)

at top, with a little *copper*.

Sp. 15017. Hole 1 at 228 feet from surface. Microlitic porphyritic, glassy amygdaloid.

Sp. 15018. Hole 1 at 254 feet from surface. Margin at 227. Poikilitic patches; olivine present with 2-3 mm. augite.

Sp. 15019. Hole 1 at 264 feet from surface. Poikilitic about as coarse as 15018 with 2 mm. augite patches.

Sp. 15020. Hole 1 at 275 feet from surface. Fine grained.

275-298; (Ss. 15021-5). MELAPHYRE; fine grained, somewhat (22) (749) ophitic, amygdaloidal for 4 feet at top and 3 feet at bottom; with prehnite, calcite and laumontite.

Sp. 15021. Hole 1 at 278 feet from surface. Fine grained amygdaloid.

Sp. 15022. Hole 1 at 293 feet from surface. Coarser, somewhat poikilitic.

Sp. 15023. Hole 1 at 295 feet from surface.

Sp. 15024. Hole 1 at 297 feet from surface. Trace of poikilitic structure, about like 15020.

Sp. 15025. Hole 1 at 298 feet from surface. Fine grained amygdaloid like 15021.

298-362; (Ss. 15026-37). MELAPHYRE, ophite; amygdaloidal (62) (811) for about 10 feet at the top, with chlorite and a little *copper;* at 316 feet vein of datolite (?) and *copper*, and at 321 feet *copper* again. It is equivalent to the flow, from the top of No. III down to 44 feet, which is also a veined ophite with a seam containing *copper*, at 19 feet.

At the very bottom of the bed are some tubular amygdules running lengthwise of the drill cores, i. e., perpendicular to the contact, which contain some calcite, chlorite, and *copper*. This horizon deserves farther attention.

Sp. 15026. Hole 1 at 298 feet from surface. Coarser than 15025 which may belong with this flow. Distance from margin 298.

Sp. 15027. Hole 1 at 298? feet from surface. Medium fine grained amygdaloid; iron oxide characteristic of ground near amygdules; calcite patches.

Grain

Olivine 5x7; 6x5; 5x7, av. .16x.19 mm.

Feldspar 26x3; 20x2; 13x3, av. .59x.08 mm.

Sp. 15028. Hole 1 at 301 feet from surface. Coarser with a trace of poikilism.

Grain

Olivine 8x6; 5x7; 6x7, av. .19x.20

Feldspar 27x4; 32x4; 30x5, av. .89x.13

Augite 17x12; 15x10; 18x13, av. .50x.35.

Sp. 15029. Hole 1 at 308 feet from surface. Similar; very feldspathic.

Grain

Olivine 8x8; 8x9; 7x15, av. .23x.32

Feldspar 20x3; 27x4; 35x4, av. .82x.11

Augite 43x25; 25x20; 30x15, av. .98x.60.

Sp. 15030. Hole 1 at 316 feet from surface. Similar; poikilitic; sand in the pores; much decomposed; all pseudomorphic feldspar.

Grain

Olivine 14; 9; 7

Iron oxide 12; 12; 10

Feldspar 30x3; 18x2; 20x3, av. .68x.08 mm.

Augite 60x30; 50x23; 77x43, av. 1.87x.96 mm.

Sp. 15031. Hole 1 at 318 feet from surface. Hardly poikilitic; very feldspathic; augite much cut up by feldspar.

Grain

Olivine 15x10; 10x10; 12x13, av. .37x.33

Feldspar 27x3; 42x3; 22x2, av. .91x.08

Augite 65x45; 30x23; 25x23, av. 1.20x.91.

Sp. 15032. Hole 1 at 320 feet from surface. Similar; rather decomposed; polysomatic? augite, hard to define.

Grain

Olivine 6; 11; 15x15; 22x3, av. .43x.29 mm.
Feldspar 30x4; 25x3; 20x3, av. .75x.10 mm.
Augite 70x40; 43x30; 120x55, av. 2.33x1.25 mm.

Sp. 15033. Hole 1 at 330 feet from surface. Slightly poikilitic.

Grain

Olivine 8; 17; 12; 20; 13; 11
Feldspar 30x5; 25x4; 53x3, av. 1.08x.12 mm.
Augite 2-3 mm.; 265; 115; 125x90, av. 5.8x3.0 mm.

The grain of the augite from 15033 to the base is plotted as k in Fig. 16 of the Isle Royale report, Vol. VI.

Sp. 15034. Hole 1 at 344 feet from surface.

Grain

Olivine 14; 5; 15; 14; 9; 10
Feldspar 32x4; 40x4; 27x6, av. .99x.14 mm.
Augite 105x100; 125x55; 105x85, av. 3.35x2.40 mm.

Sp. 15035. Hole 1 at 345 feet from surface. More markedly poikilitic.

Grain

Olivine 30x12; 20x7; 20x10, av. .70x.29 mm.
Feldspar 27x6; 25x5; 40x3, av. .92x.14 mm.
Augite 3-4 mm.; 100x80; 110x100, av. 3.5x3.00 mm.

Sp. 15036. Hole 1 at 357 feet from surface. Finer grained.

Grain

Olivine 6x10; 5x9; 7x10, av. .18x.29
Feldspar 25x4; 20x2; 20x2, av. .65x.08 mm.
Augite 10x7; 5x5; 6x11, av. .21x.23 mm.

Sp. 15037. Hole 1 at 362 feet from surface. Fine grained amygdaloid; glassy microlitic, porphyritic; N. B. There are long irregular amygdules parallel to boring the so-called pipe amygdules. Distance from margin 361½.

Grain

Feldspar phenocrysts 22x2; 21x7; 15x5, av. .85x.14 mm.
Augite 0.

362-377; (Ss. 15038-9). MELAPHYRE, amygdaloidal. Equivalent (15) (826) to drill hole No. III to 44-59.

Sp. 15038. Hole 1 at 368 feet from surface. Rather fine grained; with red olivine this time; low angled feldspar; polysomatic augite, much larger; change in character of flow.

Grain

Olivine 6x7; 5x6; 7x13, av. .18x.26 mm.
Feldspar 15x2; 22x2; 23x3, av. .60x.07mm.
Augite 12x10; 12x12; 35x5, av. .59x.27 mm.

Sp. 15039. Hole 1 at 377 feet from surface. Very fine grained, black amygdaloidal microlitic. At margin 377?

Grain

Olivine 3x5; 2x4; 3x5; av. .08x.14 mm.
Feldspar 7x3; 16x1½; 17x3, av. .40x.07 mm.

377-386; (Ss. 15040-1). MELAPHYRE, amygdaloidal. Equivalent (91) 835 in drill hole No. III to 59-67 feet.

Sp. 15040. Hole 1 at 381 feet from surface. Two different grains of coarse

amygdaloid; low angled fine grained amygdaloid; sedimentary filling to amygdaloid? from the conglomerate close below.

Grain

Olivine 6x4; 5x5; 12x4, av. .22x.13 mm.

Feldspar 25x2; 40x4; 30x5, av. .95x.11 mm.

Augite 0.

Sp. 15041. Hole 1 at 386 feet from surface. Very fine grained microlitic; porphyritic much forked.

Grain

Olivine 9x5; 5x5; 5x6, av. .19x.16 mm.

Feldspar 7x2; 15x2; 10x1, av. .32x.05 mm.

Augite 0.

Top below base of Calumet Conglomerate? (835)

386-426; (Ss. 15041-5). Kearsarge conglomerate fine grained (38) (873) amygdaloids and scoriaceous beds with basic sediment mixed and at the bottom. This is equivalent to the beds No. III, 67-110 feet, but the trap and sediment being both fine grained, it is difficult to separate them. We may be sure of having quite a marked scoriaceous CONGLOMERATE here. There is a noteworthy amount of the felsitic debris, the first such occurrence under the Allouez conglomerate, No. VI, 363 feet, and there are also agate pebbles.

I take this to be the Kearsarge conglomerate, for reasons mentioned below in connection with the Minong porphyrite. Together with the characteristic beds below it is one of the most persistent horizons of the island, and they can be traced from one end of it to the other and so might well be formed equally far away on Keweenaw Point where the Kearsarge conglomerate is very persistent also. Not all of the 38 feet assigned to this is sediment. But on the other hand the distance from this to the supposed Calumet does not show the usual shrinkage.

Sp. 15042. Hole 1 at 402 feet from surface. Open amygdaloid; glassy? chloritic. This may be a pebble, a mistake or a small overlying flow.

Grain

Olivine 5x9; 10x12; 14x13; 5x12; 9x14; 20x13, av. .34x.41 mm.

Feldspar 40x4; 43x3; 30x2, av. 1.13x.09 mm.

Augite 70x60; 120x100, av. 2.85x2.40.

Sp. 15043. Hole 1 at 412 feet from surface. Distance from margin 412. Rolled granules of augite, etc.; a calcareous sediment. Sediment=3.98 No. 15114. This is the one sedimentary section.

1. 426-456; (Ss. 15044-50). Minong PORPHYRITE; equivalent (29) (29) to No. III, 100-134 feet. This is quite acid, probably not belonging to the melaphyres at all, but rather a felsite porphyrite. No olivine can be recognized in it with certainty, either microscopically or otherwise. The character is more distinct under the microscope, but the extreme fineness of grain, the scoriaceous, porous and brecciated appearance, peculiar in that the pores are fine and irregular, can be recognized with the naked eye. We shall call this the Minong porphyrite. Elsewhere as near Todd Harbor it appears to be distinctly a felsite porphyrite, but the unaided eye could hardly distinguish it as such in the drill cores. Now we find under the lowest conglomerate in the Central mine, which Hubbard has correlated with the Kearsarge (Proc. L. S. M. I., Vol. III, 1895, p. 75) a trap which appears to be of similarly acid character, and I know of none such either on Isle Royale or in the Central mine, below the Allouez conglomerate. In the Manitou section the bed immediately beneath the Kearsarge is feldspathic but yet ophitic. But 61 is glom-

eroporphyritic. The mottling is, however, faint. The chances are that the more salic beds are not so wide spread.

More nearly similar beds are found in the Torch Lake section (Fig. 38 beds 10 to 59) and Central Mine section much lower down, and the possibility of a big gap in the Isle Royale section between the Allouez and Minong must be kept in mind. Now as to the relative position, the Kearsarge conglomerate varies from (2599) feet below the Allouez at the Central mine according to Hubbard or as I make it (2628) to (2690) to (2,239) feet at Calumet. According to our reckoning, on Isle Royale it is (from base to base) (1670) feet. This is (0.615) not far from two-thirds the thickness of the intervening beds at the Central mine, and on page 68 of the Isle Royale report we found the ratio of the distances between Marvine's No. 43 and No. 65 to be 396÷573=0.69, very much the same. As to its relations with other conglomerates, the distance between the Kearsarge conglomerate, Marvine's No. 11, and the Allouez conglomerate, his No. 15, (2599 feet) is about cut in two (1128) by th Calumete conglomerate, No. 13, and we have No. IV 135 feet, a basic sandstone about 873 feet above this conglomerate which may represent the Calumet conglomerate. At any rate a period of slackened eruptive activity in that portion of the series is marked.

Then nearer the Allouez conglomerate than the Calumet is the Houghton conglomerate, No. 14, and of that we find traces in Hole 2 at 175 feet (569) feet higher than the Calumet as compared with (815) feet at the Central. These two intermediate beds, the Calumet and the Houghton conglomerates, are much thinner and more basic in character than along Keweenaw Point, but that is what we should expect from the general thinning out of all the rocks, the ratio of thinning being similar for all these correlations. The correlation is then fairly satisfactory, and the more so, because in constructing our column we have, between drill holes No. IV and No. I, a lowed for 270 feet of faulting on other grounds than these correlations. That our correlations come out thus well, strengthens our confidence that we were right in allowing for that fault.

Sp. 15044. Hole 1 at 425 feet from bed rock surface. Very fine grained; microlitic. Distance from margin 0 ft.

The variation in grain from this point down is shown in Fig. 21 of Vol. VI, Part I, both for the feldspar and the augite.

Sp. 15045. Hole 1 at 426 feet from bed rock surface. Very fine grained.

Sp. 15046. Hole 1 at 436 feet from surface. 2 large phenocrysts, ground mass very fine grained and ferruginous.

Grain

Iron oxide 2; 3; 3

Feldspar phenocryst 62x45, av. .15x.03; microlites 4x1; 4x1; 7x1, av. .15x.03.

Sp. 15047. Hole 1 at 440 feet from surface. Very fine grained; large feldspar phenocrysts.

Sp. 15048. Hole 1 at 444 feet from surface. Very fine grained; a curious scoriaceous streak; cf. 15112; feldspar with low angled ex. and many unstriated perhaps orthoclase.

Grain

Feldspar 4x1; 6x1; 9x1, av. .19x.03 mm.

Sp. 15049. Hole 1 at 449 feet from surface. Very fine grained, yet uniform and not amygdaloidal.

Sp. 15050. Hole 1 at 456 feet from surface. Amygdaloid.

Grain

Iron oxide dust

Feldspar phenocryst 13x10; microlites 5x1; 5x1; 7x1.

1. 456-536; (Ss. 15051-5). MELAPHYRE, porphyrite, the Minong (77) (106) trap; equivalent to No. III, 135-415 feet. It is sometimes faintly mottled toward the lower third of its thickness, but in general it is much finer grained for its size than the ophites. It is compact and has a clean conchoidal fracture, and tends to basaltic jointing. Occasional fair-sized carnelian agates are a feature of this bed. On the other hand it differs from the porphyrites above the Greenstone aside from microscopic characters by being much darker black, rather than grayish green. It can be traced almost continuously the full length of the island, from a projecting point on the north line of Sec. 35, T. 64, R. 39, through the Wendigo property, where the trail running from Sec. 20 to Sec. 15 (Pl. III) is nearly along its outcrop. Its lower contact was opened up by numerous costeans on the northwest side and by tunnel No. 5. It runs along the south side of Todd Harbor, where it was again developed by costeans (I and II), and at McCulloch's mine (p. 5). Passing near the west quarter post of Sec. 27, T. 66, R. 35, it formed the foot of the more extensive workings of the Minong mine (though there was also some test-pitting under it), and thence may be followed to the north side of Locke Point. It appears to be good road metal, and is much like a bed in the Torch Lake section No. 59 (Hole 5) and some of the beds from 81 to 115 in the Central Mine section (Fig. 33.) Compare especially bed 96 and 97. I am more inclined to think now than when writing Vol. VI that the line of Washington Harbor may not only mark a fault (I have indicated that) but a considerable one, cutting out a good bit of the series. If this is bed 97 of the Central Mine section instead of 43 some (2329) feet of that section would be omitted here. Such a fault would be of the slide fault nature a strike fault with the down throw on the south side. This bed is notably feldspathic and remarkably fine grained for so thick a flow, another sign of its salic character.

At the bottom of this flow we pass from the record of drill hole No. 1 to that of No. III. No. I, 536 feet, is equivalent to No. III, 215 feet, i. e., 321 feet higher. Adding the excess of elevation of No. III over No. I (231-164=67 feet) we have 388 feet difference in level, which divided by 1,518 feet, the distance between the two holes in the direction of the cross-section, gives a dip of 14° 20′. This is the most accurately determined dip that we have, and we get the same result by supposing that the bottom of No. V just laps the top of No. I, and again by correlating No. III and No. XIII. Stockly's determination from the outcrop at the surface near tunnel No. 5, was practically the same (14¼°). There is no indication of a fault between No. 1 and No. III, and there is no possibility of much of a fault.

Sp. 15051. Hole 1 at 460 feet from surface. Coarse, yet still fine grained and amygdaloidal.

Grain

Iron oxide dust

Feldspar 8; 1; 4; 1; 7; 1, av. 0.19x.03 mm.

Sp. 15052. Hole 1 at 483 feet from surface. Streaks with coarser feldspar and glass mixed with finer shale? One corroded phenocryst or brotocryst is shown in Fig. 6, Plate VI, Vol. VI which also shows the general texture and a blotchy intermixture of coarser and finer textures. The augite is sharply idiomorphic in small square shaped granules.

Grain

Augite 2; 1; 3; 2; 3; 3; 3; 2.

Sp. 15053. Hole 1 at 500 feet from surface. Fine grained poikilitic; much iron oxide; very feldspathic.

Grain.

Olivine 4x4; 9x4; 9x5; 7, av. .22x.13

Feldspar 7x1; 13x1; 10x2, av. .30x.04

Augite 40x25; 32x22; 35x23, av. 1.07x0.70 and observations with the naked eye also give 0.7, 0.8, 1.0 about 1 mm.

Sp. 15054. Hole 1 at 512 feet from surface. Very fine grained, poikilitic; with a little olivine.

Grain

Olivine 4x5; 5x5; 3x5, av. .12x.15

Feldspar 7x2; 9x1; 11x2, av. .27x.05

Augite 25x11; 14x11; 40x33, av. .79x.55.

Sp. 15055. Hole 1 at 536 feet from surface. Contact of two traps; little sediment in the amygdules of the upper one; microlitic and trichitic; black; upper one probably more glassy and finer grained. At margin 536 ft.

Grain

Feldspar phenocrysts 12x8; 10x4; 24x4, av. .46x.20; microlites 6x1; 4x2; 6x1, av. .16x.04

Compare Sp. 15122.

Sp. 15056. Hole 1 at 538 feet from surface. Large and small olivine; amygdaloidal.

Grain

Olivine phenocrysts 23x10; 20x15; smaller size 3x3; 6x4; 6x7, av. .15x.14

Feldspar 18x5; 23x4; 8x1, av. .49x.10 mm.

Augite 0.

Sp. 15057. Hole 1 at 539 feet from surface. Slightly poikilitic.

Grain

Olivine phenocrysts 12x10; 8x10, av. .33x.33

Smaller size 10x5; 5x9; av. 25x23.

Feldspar 12x2; 12x2; 19x4, av. .43x.08

Augite 18x13; 20x15; 20x18, av. .58x.46.

Sp. 15058. Hole 1 at 573 feet from surface. Rather porphyritic; average labradorite feldspar smaller and coarser; and more poikilitic than 15057.

Grain

Olivine 12x6; 9x5; 6x7, av. .27x.18 mm.

Feldspar 10x5; 18x6; 23x7, av. .51x.18 mm.

Augite 80x50; 95x80; 85x80, av. 2.60x2.10 mm.

Sp. 15059. Hole 1 at 580 feet from surface. Still coarser; feldspar still abundant; really coarser than 15058 but more polysomatic.

Grain

Olivine 6x12; 6x10; 7x13, av. .19x.35 mm.

Feldspar 15x5; 27x3; 13x3, av. .55x.11 mm.

Augite 65x33; 80x70; 63x55, av. 2.08x1.58 mm.

Sp. 15060. Hole 1 at 600 feet from surface. Drusic chlorite cavities; semi-amygdaloidal; feldspar extinction angles 25°-30°; 28°-32°w5°.

Grain

Olivine 15x12; 11x14; 11; 9, av. .38x.33 mm.

Feldspar 14x3; 17x2; 22x3, av. .53x.08 mm.

Augite 2-4 mm. by eye; 90x80; 96x75; 130x80, av. 3.16x2.45 mm.

Sp. 15061. Hole 1 at 627 feet from surface. Microlitic; finer grained than 15060; irregular contact with sediment which may be a clasolite.

Grain

Olivine 5x13; 4x10; 3x7, av. .12x.30 mm.

Feldspar 19x2; 14x2; 24x4, av. .57x.08 mm.

Sp. 15063. Hole 1 at 635 feet from surface. About the same grain as 15062.

Grain

·Olivine 7x6; 4x9; 5x10, av. .16x.25 mm.

Feldspar 11x2; 20x2; 24x2, av. .55x.06 mm.

Sp. 15064. Hole 1 at 666 feet from surface. Much reddish olivine.

Grain

Olivine 6x9; 6x5; 7x9, av. .19x.23 mm.

Feldspar 16x4; 15x2; 20x2, av. .51x.08 mm.

Sp. 15065. Hole 1 at 670 feet from surface. Fine grained sediment; rounded grains (4, 3, 25 thirtieths of an mm.) of augite and feldspar.

Sp. 15066. Hole 1 at 695 feet from surface. Poikilitic.

Grain

Olivine 12x7; 12x7; 11x10, av. .35x.24 mm.

Feldspar 16x4; 12x3; 18x3, av. .46x.10 mm.

Augite 2-3 mm. by eye; 40x26; 100x70; 70x60, av. 2.10x1.56 mm.

Sp. 15104. Hole 3 at 2 feet from surface.

Sp. 15104-15105 are from bed III down to 44 equivalent to the lower part of I. 298 to 362 feet. The rock at the beginning is coarse enough to indicate 20 or 30 feet more of the flow above it. Poikilitic. Coarser feldspar and vein. Contact of two flows.

Grain

Augite 2-3 mm.

Sp. 15105. Hole 3 at 17 feet from surface. Decomposed poikilitic augite in large patches but much feldspar.

Grain

Olivine 5x10; 8x14; 5x15, av. .18x.39 mm.

Feldspar 43x8; 35x5; 38x6, av. 1.16x.19 mm.

Augite 53x42; 48x42; 57x25, av. 1.58x1.09 mm.

Sp. 15106-15107 are from the bed III 44-59 feet equivalent to I 362-377.

Sp. 15106. Hole 3 at 44 feet from surface. Brown glass at margin; yellow olivine; is this brown glass found at margins higher in series?

Grain

Olivine 6x15; 8x8; 6x14, av. .20x.37 mm.

Feldspar 22x3; 16x3; 12x3, av. .50x.09 mm.

Sp. 15107. Hole 3 at 46 feet from surface. Microlitic amygdaloid with coarser spots; numerous small feldspars.

Grain

Olivine 4x4; 5x5; 4x4, av. .13x.13 mm.

Feldspar phenocrysts 13x3; 10x1; 9x2, av. .32x.06 mm.

Sp. 15108-15109 are from the bed III 59-67 feet equivalent to I. 377-386.

Sp. 15108. Hole 3 at 56 feet from surface. Not very fine grained; very feldspathic; andesite feldspar.

Grain

Olivine 17x17; 14x9; 13x10, av. .44x.36 mm.

Feldspar 33x2; 16x1; 25x2, av. .74x.05 mm.

Augite 10x9; 30x12; 18x16, av. .58x.37 mm.

Sp. 15109. Hole 3 at 60 feet from surface. Somewhat poikilitic.

Grain

Olivine 11x9; 10x9; 11x10, av. .32x.28 mm.

Feldspar 23x4; 21x5; 30x4, av. .74x.13 mm.

Augite 25x13; 30x26; 33x30, av. .88x.69 mm.

Sp. 15110 to 15113 are from the bed 3.67-110 equivalent to 1.386-426.

Sp. 15110. Hole 3 at 68 feet from surface. Brown glass; phenocryst amygdaloids; the microlites are 2 to 3x.1.

Grain

Olivine 7; 6

Feldspar phenocrysts 18x2; 13x2; 13x3, av. .44x.07.

Sp. 15111. Hole 3 at 77 feet from surface. Coarser; low angled; feldspathic; slightly amygdaloidal.

Grain

Olivine 8x7; 6x9; 10x10, av. .24x.26 mm.

Feldspar 28x4; 23x4; 22x4, av. .73x.12 mm.

Augite 10x10; 18x10; 20x13, av. .48x.33 mm.

Sp. 15112. Hole 3 at 88 feet from surface. Curious drawn out cavities; not very fine grained; cf. 15048; low angled feldspar.

Grain

Olivine 6x9; 4x8; 7x4, av. .17x.21 mm.

Feldspar 16x3; 18x2; 18x2, av. .52x.07 mm.

Augite 12x5; 11x8; 10x4, av. .33x.17 mm.

Sp. 15113. Hole 3 at 93 feet from surface. Somewhat poikilitic; chloritic.

Grain

Olivine 10x7; 12x9; 15x9, av. .37x.25 mm.

Feldspar 34x4; 16x3; 18x5, av. .68x.12 mm.

Augite 30x27; 25x18; 25x25, av. .80x.70 mm.

Sp. 15114 (Hole 3 at 98 ft.-100?) is perhaps the Kearsarge Conglomerate, anyway=1. somewhere between 386 and 426.

Sp. 15114. Hole 3 at 98 feet from surface.

(A) Sediment not very fine grained 2, 2, 10, 12.

(B) Melaphyre not very fine grained

Grain

Olivine 10

Feldspar 20x3

Augite 2.

(C) Melaphyre finer grained; brown glass.

Grain

Olivine 4

Iron oxide 4x.1

Feldspar 15x2.

Sp. 15115-15118 may be a separate flow or combined with 15122 in the porphyrites.

Sp. 15115. Hole 3 at 100 feet from surface. Fine grained amygdaloid with flow lines.

Grain

Olivine 2x3; 2x1; 2, 1

Feldspar 5x1; 15x1.5; 7x1, av. .27x.03 mm.

Sp. 15116. Hole 3 at 110 feet from surface. Very fine grained with minute irregular amygdules suggestive of a salic rock; ground mass of low angled feldspar.

Grain

Olivine?

Feldspar 7x1; 8x1; 5x1, av. .20x.03 mm.

Augite 1?

Sp. 15117. Hole 3 at 122 feet from surface. Vitreous; minute pores; around them in some parts finer grained so that even the feldspar measured seems porphyritic. They have black borders and the irregular shape of acid pores.

Grain

Olivine 0?

Iron oxide .2; .3; .4; .5; 3; 3; 1, av. .07x.01 mm.

Feldspar 5x1; 7x1; 7x1, av. .19x.03 mm.

Sp. 15118. Hole 3 at 134 feet from surface. Very light color and very fine grained.

Grain

Feldspar 7x2; 8x1; 8x1, av. .23x.04 mm.

Augite 1x1; 1x1; 2x1, av. .04x.03 mm.

Sp. 15119. Hole 3 at 148 feet from surface. Fine grained iron oxide dots.

Grain

Iron oxide 4x4; 4x6; 8x6, av. .16x.16 mm.

Feldspar 12x1; 14x2; 9x1, av. .35x.04 mm.

Augite 1x2; 5x1; 2x2, av. .08x.05 mm.

Sp. 15120. Hole 3 at 150 feet from surface. Fine grained; very curious contact with chalcedonic layer of coarser grain; datolite.

Grain

Iron oxide 4x4; 4x5; 6x5, av. .14x.14 mm.

Feldspar 8x1; 11x1; 7x1, av. .26x.03 mm.

Augite 7x4; 1x1; 6x4, av. .14x.09 mm.

Sp. 15121. Hole 3 at 187 feet from surface. Somewhat poikilitic; some olivine, labradorite extinction angles 35°-32°; 13°-12°w3°.

Grain

Olivine 7; 7.

Iron oxide 8x4; 5x7; 6x9, av. .19x.20 mm.

Feldspar 9x2; 12x1; 12x1, av. .33x.04 mm.

Augite 42x30; 65x40; 30x30, av. 1.37x1.00 mm.

Sp. 15122. Hole 3 at 215 feet from surface. Very fine grained.

Grain

Iron oxide 1x1; 2x2; 1x1, av. .04x.04 mm.

Feldspar 5x1; 8x1; 10x1, av. .23x.03 mm.

Augite 1x2; 1x1; 1x2, av. .03x.05 mm.

DRILL HOLE No. III

III. 215-309; (Ss. 15123-8). MELAPHYRE, ophite; equivalent $\frac{(91)\ (197)}{\quad}$ to No. I, 536-630 feet (Ss. 15056-61); quite amygdaloidal at top, with traces of a sedimentary parting.

The grain of the augite of this bed is given by h in Fig. 16 of Vol. VI, Part I. The rate of increase and coarseness of the augite at the bottom are exceptionally large. It thus stands in marked contrast to the beds above.

Sp. 15123. Hole 3 at 216 feet from surface. Fine grained amygdaloidal with blacker spots.

Grain

Olivine 1? 1; 2; 2

Feldspar 6x1; 5x1; 6x0.5.

Sp. 15124. Hole 3 at 223 feet from surface. Much decomposed; augite in queer aggregates.

Grain

Olivine 5x5; 18x4; 5x5, av. .28x.14 mm.

Feldspar much decomposed 18x4

Augite 20x4; 35x30; 40x35, av. .95x.69 mm.

Sp. 15125. Hole 3 at 230 feet from surface. Poikilitic; olivine plain.

Grain

Olivine 20x9; 15x10; 20x13, av. .55x.32 mm.

Feldspar 16x7; 19x4; 18x4

Augite 44x28; 80x70; 55x40, av. 1.79x1.38 mm.

Sp. 15126. Hole 3 at 254 feet from surface. Very coarse poikilitic; this corresponds to Marvine's light type of diorite, that is has a doleritic texture; labradorite extinction 16°-13°w41°-36°; 31°-40°w21 (larger extinction at center).

The interstices are filled with irregular probably secondary quartz shot through with apatite needles. The augite is not so thoroughly moulded upon the feldspar as usual. It has more of its own form and cuts into the feldspar. The magnetite is unusually coarse.

Grain

Olivine none.

Iron oxides 16x10; 18x13; 25x22, av. .60x.45 mm.

Feldspar 56x9; 90x24; 75x7, av. 2.21x.40 mm.

Augite 80x45; 42x25; 50x50, av. 1.72x1.20 mm.

Sp. 15127. Hole 3 at 285 feet from surface. Marked poikilitic.

Grain

Olivine 5x8; 9x9; 7x6, av. .21x.23

Feldspar 20x11; 12x4; 22x4, av. .54x.19

Augite 2-3 mm. (with naked eye); 130x115; 160x90; 130x130, av. 4.20x3.35 mm.

Sp. 15128. Hole 3 at 307 feet from surface. Finer grained poikilitic.

Grain

Olivine 9x18; 12x15; 12x13, av. .33x.46

Feldspar 20x6; 18x4; 10x3, av. .48x.13

Augite with naked eye 1-2 mm.; 25x20; 36x21; 40x40, av. 1.01x0.81 mm.

309; (S. 15129). Sediment, i. e., SHALE; mainly composed (0?) (197) of plagioclase feldspar, but there is some quartz in it; cf. No. I, 630 feet; may perhaps be two or three feet thick. Cf. Wolverine sandstone, a wind blown deposit (?) since it seems to show much mechanical very little chemical action.

309-339; (Ss. 15130-3). MELAPHYRE, amygdaloidal. Veined (29) (226) and seamed; very feldspathic; corresponds to No. I, 630-662 feet (Ss. 15062-15066).

Sp. 15130. Hole 3 at 311 feet from surface. Thoroughly decomposed? contact of sediment and glassy ground mass?

Sp. 15131. Hole 3 at 312 feet from surface. Coarse amygdaloid; olivine plain.

Grain

Olivine 10x5; 10x6; 9x9, av. .29x.20 mm.

Feldspar 15x3; 11x2; 17x3, av. .43x.08 mm.

Sp. 15132. Hole 3 at 326 feet from surface. Coarser; very feldspathic.

Grain

Olivine 9x8; 10x6; 11x11, av. .30x.25 mm.

Feldspar 19x2; 22x2; 15x3, av. .56x.07 mm.

Augite 7x5; 9x8; 10x9 and at times larger, but hardly porphyritic, av. .26x.22.

Sp. 15133. Hole 3 at 339 feet from surface. Feldspathic, olivine changes to magnetite. Margin at 339 ft.

Grain

Olivine 8x5; 10x8; 8x4, av. .26x.17 mm.

Feldspar 16x2; 13x1; 19x2, av. .48x.05 mm.

Augite 2; 1; 2x2, av. .05 mm.

3.339-363; (S. 15134). MELAPHYRE, amygdaloidal; drill hole (23) (249) 1,602-700 ?

No. I extends down to 700 feet, but is much decomposed in the lowest part, and the beds there are not easily separable. Poikilitic, basic feldspar.

Grain

Olivine 6x9; 9x10; 8x10, av. .23x.29 mm.
Feldspar 21x2; 15x3; 25x10, av. .61x.15 mm.
Augite 28x25; 17x17; 50x30, av. .95x.72 mm.

363-410; (Ss. 15135-8). OPHITE, amygdaloidal; possibly (45) (294) two flows, separated at 380 feet. Compare bottom of Hole 1.

Sp. 15135. Hole 3 at 367 feet from surface. Rather fine grained; slightly poikilitic.

Grain

Olivine 4x5; 7x4; 6x2, av. .17x.11 mm.
Feldspar 20x1; 18x2; 15x3, av. .53x.06 mm.
Augite 12; 13x8; 34x22.

Sp. 15136. Hole 3 at 376 feet from surface. Marked poikilitic but in polysomatic aggregates; basic feldspar.

Grain

Olivine 15x12; 9x8; 14x10, av. .38x.30
Feldspar 14x3; 28x4; 19x5, av. .61x.12 mm.
Augite 40x40; 70x25; 40x30, av. 1.50x.95 mm.

Sp. 15137. Hole 3 at 380 feet from surface. Similar; rather finer.

Grain

Olivine 8x7; 7x7; 11x7, av. .26x.21 mm.
Feldspar 20x2; 16x3; 19x3, av. .55x.08 mm.
Augite 43x28; 48x32; 54x13, av. 1.45x.73 mm.

Sp. 15138. Hole 3 at 393 feet from surface. Similar; coarser; feldspar extinctions 27°-21°.

Grain

Olivine 12; 13; 6
Iron oxide 12; 12; 10
Augite 65x55; 40x40; 63x53, av. 1.68x1.48 mm.

410-453; (Ss. 15139-42). MELAPHYRE, ophite (42) (336)

Sp. 15139. Hole 3 at 410 feet from surface. Marked microlitic porphyritic. Near margin 410 ft.

Grain

Olivine 6x2; 10x6; 4x3, av. .20x.11 mm.
Feldspar phenocrysts 10x1; 15x3; 13x10, av. .38x.24 mm.
Augite 0.

Sp. 15140. Hole 3 at 420 feet from surface. Very ´eldspathic.

Grain

Olivine 11x4; 10x8; 15x7, av. .36x.19 mm.
Feldspar 15x3; 19x3; 12x2, av. .46x.08 mm.
Augite 2x3; 3x8; 2x3, av. .14x.07 mm.

Sp. 15141. Hole 3 at 424 feet from surface. Thoroughly decomposed; traversed by prehnite vein.

Grain

Olivine 6x3; 7x5; 4
Feldspar 15x4?.augite and feldspar are all decomposed.

Sp. 15142. Hole 3 at 440 feet from surface. Poikilitic.

Grain

Olivine 16x8; 15x8; 10x7, av. .41x.23 mm.
Feldspar 24x3; 14x1; 23x4, av. .61x.08 mm.
Augite 47x42; 90x60; 66x45, av. 2.03x1.47 mm.

453-473; (Ss. 15143-4). MELAPHYRE, feldspathic (19) (355)

Sp. 15143. Hole 3 at 453 feet from surface. Little augite; mostly feldspar.

Grain

Olivine 8x7; 7x6; 12x7, av. .27x.20 mm.

Feldspar 15x2; 19x3; 17x7, av. .51x.12 mm.

Augite 12x13; 6x5; 14x6, av. .32x.24 mm.

Sp. 15144. Hole 3 at 464 feet from surface. Rather feldspathic.

Grain

Olivine 8x7; 9x6; 13x9, av. .30x.15 mm.

Feldspar 33x4; 24x3; 21x3, av. .78x.10 mm.

Augite 18x18; 30x22; 60x50, av. 1.08x.90 mm.

473-562; (Ss. 15145-51). MELAPHYRE, ophite; at 497 feet (86) (441)

the drillers are said to have struck a vein and to have followed it for 82 feet. They may have approached it at 424. S. 15149 at 496 feet and S. 15150 at 545 feet show a prehnite and calcite vein with crystallized copper.

Sp. 15145. Hole 3 at 473 feet from surface. Fine grained with a certain amount of glass; feldspar (seriate) varying in size.

Grain

Olivine 4x3; 7x4; 6x4, av. .17x.11 mm.

Feldspar 13x3; 18x3; 20x3, av. .15x.09 mm.

Augite 0.

Sp. 15146. Hole 3 at 478 feet from surface. Slightly augitic; feldspar low angled.

Grain

Olivine 6x5; 9x8; 10x6, av. .25x.19 mm.

Feldspar 18x2; 18x2; 20x3, av. .56x.07 mm.

Augite 20x8; 30x20; 18x15, av. .68x.43 mm.

Sp. 15147. Hole 3 at 490 feet from surface. Poikilitic; low angled feldspar.

Grain

Olivine 10x9; 12x8; 7x5, av. .29x.24 mm.

Feldspar 21x3; 23x3; 21x3, av. .65x.09 mm.

Augite 40x31; 60x60; 54x50, av. 1.54x1.41 mm.

Sp. 15148. Hole 3 at 496 feet from surface. Coarse feldspar; doleritic texture like Marvine's light type of diorite, augite and olivine if present largely altered to serpentine; feldspar ex. angles 7°-8°, 12°-16°; olivine is therefore uncertain.

Grain

Olivine ? (25)

Iron oxide 25x3

Feldspar 32x10; 49x10; 44x14, av. 1.25x.34 mm.

Augite 80x20; 65x40; 28x30, av. 1.73x.90 mm.

In one place there is a nest of augite like a fragment of a pyroxenite.

Sp. 15149. Hole 3 at 498 feet from surface. A little finer; feldspar very low angled; augite somewhat poikilitic but much cut up by feldspar; prehnite vein with crystals of copper; augite.

Grain

Olivine 10x5; 7x6; 9x7, av. .26x.18 mm.

Feldspar 22x4; 18x2; 11x8; 22x5, av. .60x.16 mm.

Augite 90x60; 65x40; 100x60, av. 2.55x1.60 mm.

Sp. 15150. Hole 3 at 545 feet from surface. Vein matter; calcite and prehnite gangue with copper, and much iron oxide.

Sp. 15151. Hole 3 at 561 feet from surface. Somewhat poikilitic.

Grain

Olivine 9x6; 7x4; 7, av. 0.23x0.15 mm.

Iron oxide 12; 7; 11; 8

Feldspar 28x3; 23x4; 20x3, av. .71x.10 mm.

Augite 70x15; 54x13; 45x30, av. 1.69x.58 mm.

Sp. 15152. Hole 3 at 563 feet from surface. Rather fine grained; amygdaloidal.

Grain

Feldspar 19x2; 21x1; 13x3, av. .53x.06.

Sp. 15153. Hole 3 at 583 feet from surface. Quite feldspathic; with red and white olivine pseudomorphs.

Grain

Olivine 15x7; 15x14; 18x12, av. .48x.33 mm.

Feldspar 24x4; 38x6; 32x5, av. .94x.15 mm.

Augite 13x12; 16x14; 20x13, av. .49x.39 mm.

Sp. 15154. Hole 3 at 619 feet from surface. Well marked poikilitic; green olivine; feldspar has very marked zonar extinctions.

Grain

Olivine 17x18; 19x15; 13x10, av. .49x.43 mm.

Iron oxide 25x3; 16x2; 10x6, av. .51x.11 mm.

Feldspar 58x11; 47x7; 70x14, av. 1.75x.32 mm.

Augite 92x74; 100x79; 80x75, av. 2.72x2.28 mm.

DRILL HOLE XIII.

At this point it seems best to pass to drill hole No. XIII, whose beginning is in a band of very chloritic amygdaloid close to the north of some bluffs of ophite. Two holes were put down here, one vertical and the other, No. XIIIA, at an angle of 45° to the east. Drill hole No. XIII is somewhat farther from tunnel No. 5, which is in the foot of the Minong trap (drill hole No. I, 536 feet -No. III, 215 feet), than the tunnel is from drill hole No. I. The distance from No. III to No. XIII is 1775 feet and the top of No. III is (231-216) 15 feet the lower. Hence, allowing the dip slope to be 1:4 (tan 14-½°) the top of No. XIII, in the absence of faults, would correspond to No. III, 459 feet. The first samples of the vertical hole No. XIII were accidentally mixed from 31 feet to 113 feet, so that we shall have to use the record of No. XIIIA for this part of our section. In hole No. XIII the rock grows less amygdaloidal after the first 17 feet and in hole No. XIIIA after the first 35 feet (reduced to the vertical which we will indicate by prefixing v, e. g. v. 25), then the hole passes into a uniform looking gray ophite which begins to be finer grained about 79 feet (v. 56 feet), but we do not reach its bottom, for at 86 feet (v. 61 feet), we cross a fissure, which this hole intended to cut. Only such holes show veins at right angles to the strike. Then, at 132 feet (v. 93 feet), comes a marked contact of two quite amygdaloidal flows, with copper and prehnite in the amygdules. The impregnation of copper and prehnite here and in Hole III may be from this fissure. From this point the rock is once more a massive ophite down to 208 feet (v. 147 feet), where there is another contact, with a band of basic sandstone. In No. XIII we have no distinct record until after 113 feet; then we meet a contact with a little sandstone at 125 feet. After this the rock is coarse grained down to 166 feet, when it becomes finer and grows amygdaloidal with vertical clay seams, down to 240 feet. At 230 feet we find a foot of sandstone like that at 125 feet. There are petrographic reasons, in the nature of the feldspar in the adjoining flows, for thinking that No. XIIIA (v. 93 feet) corresponds to No. XIII, 125 feet. If we suppose, as indicated

by the dip, that the amygdaloid at the top of No. XIII is that which occurs in No. III, 453 feet, then the first 17 to 25 feet of amygdaloidal rock will correspond to a point in No. III, down about 473 feet. Then for the bottom contact of the big ophite next below, at No. III, 562 feet, our first match will be No. XIII, 125 feet, and No. XIIIA (v. 93 feet). If we compute the dips from these correlations, we find that we have from No. XIII to No. III, tan 13° 20′; or tan 14° 20′.

It is not likely that the dip is becoming flatter as we go northwest from this point, for in general it grows steeper in that direction, and the dip about No. III was determined with the aid of No. 5 tunnel, as 14° 15′. It is therefore probable that the lower part of No. XIIIA is more nearly in undisturbed relations with No. III, 562 feet, than is No. XIII, though the dip may be steeper than thus indicated. Then the fault which cuts No. XIIIA at 86 feet must separate No. III, 562 feet, from No. XIII, 125 feet. It has an upthrow of (125-93) 32 feet, and in that case the amygdaloid at the top of No. XIII should correspond to No. III, 437 feet, but this is not a good correlation at all. The correlation found by assuming that the ground between the top of No. XIII and No. III is undisturbed, i. e., that No. XIII, 0 feet, is equivalent to No. III, 468 feet, is much better. If we accept this correlation, we must imagine that the fissure vein which crossed No. XIIIA crosses No. III also, probably being the vein entering at No. III, 497 feet, and throwing the part above up. Now drill holes Nos. XII, XIV, XIII, tunnel No. 5 and drill holes Nos. III and I, were all located near a supposed fault or vein which is indicated by a topographic break that runs a little east of north. A vein in about this position was indicated on Hill's map, 1871. Such a fault, if a normal fault with a hade slightly to the west, is just the one to have done the work we have attributed to it, passing a little to the east of No. XIII and No. III, but cutting into No. III at 497 feet. Figure 11 of the Isle Royale Report illustrates it, looking in the direction of the strike of rocks. There is a fissure that comes into No. XIII at about 252 feet or a little higher, and in that report is computed what the dip of the *fault* would be if the latter were a continuation of the former.

It is then quite likely that this *fault* has cut 31 feet out of the thickness of the ophite No. III, 473-562, and a corresponding amount out of No. III near No. XIII, 252 feet. Following our general rule, however, that we shall make the series as short as possible, we shall make no additions for this in our geological column. This is the third time at least that there is reason to believe this column as given is somewhat short of the truth.

The record of drill hole No. XIII is then as follows:

Sp. 15706. Hole 13 at 21 feet from surface. Amygdaloidal or merely drusic?; low angled feldspar.

Grain

Olivine 6x5; 7x6; 10x5, av. .23x.16 mm.

Feldspar 20x2; 18x1; 25x2, av. .63x.05 mm.

Augite 25x12; 25x23; 40x10, av. .90x.45 mm.

Sp. 15707. Hole 13 at 25 feet from surface. Poikilism more marked; irregular cavity lined with chloritic fibres; low angled feldspar.

Grain

Iron oxide 9x9; 5x9; 9; 12, av. .23x.3 mm.

Feldspar 24x2; 18x3; 21x1.5, av. .63x.06 mm.

Augite by eye 3 mm.; 155x100; 130x80; 210x80, av. 4.95x3.60 mm.

Sp. 15708. Hole 13A at 74 feet from surface. Finer grained than No. 15707 but similarly poikilitic; moderately low angled andesite feldspar.

Sp. 15709. Hole 13A at 79 feet from surface. Still finer than 15708; low angled feldspar. Olivine reddened.

Sp. 15710. Hole 13A at 85 feet from surface. Much serpentinized olivine and feldspar; big feldspar phenocrysts; low angled andesite feldspar.

Sp. 15711. Hole 13A at 87 feet from surface. Coarser; low angled feldspar.

Grain

Olivine 20

Feldspar 30x8

Augite 23x18.

Sp. 15712. Hole 13 at 89 feet from surface. Like Sp. 15711 but slightly coarser; low angled feldspar and much of it.

G ain·

Olivine 10x10; 10x13; 7x14, av. .27x.37 mm.

Feldspar 53x5; 50x4; 36x5, av. 1.39x.14 mm.

Augite 78x55; 120x60; 110x85, av. 3.08x2.00 mm.

Sp. 15713. Hole 13A at 123 feet from surface. No coarser than Sp. 15711 much olivine; feldspar extinction angles 45°-45°; anorthite 29°-0°; 23° labradorite.

Sp. 15714. Hole 13A at 132 feet from surface. Marked contact; rock microlitic porphyritic with brown glass; probably bottom. Feldspar phenocrysts 32x13 with trichitic additions.

Sp. 15715. Hole 13A at 133 feet from surface. Microlitic amygdaloid; coarser; very feldspathic originally; all prehnite now. Is this the Kearsarge lode?

Sp. 15716. Hole 13A at 135 feet from surface. Coarser; small chlorite pores; low angled feldspar.

Sp. 15717. Hole 13A at 137 feet from surface. Finer grained; thoroughly decomposed.

Sp. 15718. Hole 13 at 100 feet from surface. Coarse green olivine and marked augite; feldspar a basic labradorite near anorthite; feldspar extinction angles 12°-24°w39°-37°; 12°-16°w22°-34°; 0°-27°w50°-30°; 43°-40°; 17°-8°-32°.

Grain

Olivine 15x10; 22x15; 18x15, av. .55x.40 mm.

Feldspar 53x9; 30x4; 63x5, av. 1.46x.18 mm.

Augite with naked eye 3 mm.; 140x80; 80x80; 95x65, av. 3.15x2.25 mm.

Sp. 15719. Hole 13A at 160 feet from surface. Coarse poikilitic; not so much olivine; feldspar extinction angles 21°w31°-41°; 32°-16°w22°-34°.

Grain

Augite 60x60; 70x60, av. 2.1x2 mm.

Sp. 15720. Hole 13 at 117 feet from surface. Coarse poikilitic very basic feldspar.

Grain

Olivine 10x13; 7x7; 23x15, av. .40x.35 mm.

Feldspar 18x4; 23x5; 38x7, av. .79x.16 mm.

Augite 130x70; 70x65; 75x60, av. 2.75x1.95 mm.

Sp. 15721. Hole 13 at 125 feet from surface. Slightly amygdaloidal; idiomorphic augite prisms; extra reddish.

Grain

Olivine 9x11; 7x10; 8x8, av. .24x.29

Feldspar 12x4; 10x2; phenocrysts 40x15!

Augite 33x10; 46x7; 52x20, av. 1.31x.37.

If the sandstone below is as suggested in the Isle Royale report Marvine's slaty sandstone No. 9, this bed just above it would correspond to the foot of the Kearsarge lode which is characterized by being at the same time somewhat ophitic and having large feldspar phenocrysts. This section 15721 seems to show one of these phenocrysts.

The copper at 3.496 and 545 feet may remind one of the Kearsarge lode. Compare also Sp. 15714 and 15715.

13. 125-126; (S. 15722) SANDSTONE, the Wolverine, (1) (441) (442)

Marvine's No. 9? basic and red.

Sediment is made up of granules of augite and plagioclase? with a few of ground mass about 2x3 to 6x5 thirtieths of a mm.

See remarks above and on the bed at 13.229 feet.

126-184; (Ss. 15723-41). MELAPHYRE, ophite (56) (498)

Sp. 15723. Hole 13 at 127 feet from surface. Microlitic; porphyritic; feldspar not very basic.

Grain

Olivine 11x10; 11x7; 12x8, av. .34x.25 mm.
Feldspar 12x2; 15x3; 14x3, av. .41x.08 mm.
Augite 0.

Sp. 15724. Hole 13 at 137 from surface. Non-poikilitic yet very feldspathic; feldspar not very basic, low angled.

Grain

Olivine 27x18; 15x12; 13x13, av. .55x.43 mm.
Feldspar 55x5; 39x5; 60x6, av. 1.54x.16 mm.
Augite 70x36; 38x25; 80x36, av. 1.88x.97 mm.

Sp. 15725. Hole 13A at 175 feet from surface. Ophitic; labradorite extinction 22° to 38°-34°?; mostly iron oxide instead of olivine.

Sp. 15726. Hole 13A at 197 feet from surface. Similar extinction angles 4°-4°; 12°-0°. Perhaps the two sections interchanged.

Sp. 15727. Hole 13A at 204 feet from surface. Similar; (coarser); low angled?

Sp. 15728. Hole 13A at 208 feet from surface. Microlitic, porphyritic contact with basic sediment. Basic sediment is like that at 125-126 feet, but on account of the fact that above and below are andesitic beds the original correlation of 13A-133-135 with 13.125-127 is probably better. It matches 3.563 well.

Sp. 15729. Hole 13A at 214 feet from surface. Feldspar not very basic; extinctions 8°w9°-13°; 15°-15°; 10°-7°.

Olivine is altered,—red with green center.

Sp. 15730. Hole 13A at 218 feet from surface. Fine grained amygdaloid with finer grain around amygdules andesite 19°-8°; 15°-0°.

Sp. 15731. Hole 13A at 219 feet from surface. There is a change of about a quarter of the olivine to serpentine and mica. Very feldspathic; low angled andesite; extinctions 11°-6°.

Sp. 15732. Hole 13A at 234 feet from surface. Very fine grained, but like 15730; very feldspathic and microlitic.

Sp. 15733. Hole 13 at 146 feet from surface.

Sp. 15734. Hole 13 at 156 feet from surface. Quite feldspathic; slightly poikilitic; feldspar extinction angles 15°-15°; 0°w13°-9°.

Grain

Iron oxide 10x12; 10x11; 20x21, av. .40x.44
Feldspar 30x3; 30x3; 30x7, av. .90x.13
Augite 45x18; 48x25; 60x20, av. 1.53x.63.

Sp. 15735. Hole 13 at 160 feet from surface. Poikilitic; much green olivine; feldspar extinctions 24°-21°; 9°; 3°; 12° with 47°-38°; 10-17°w35° in Baveno twins.

Grain

Iron oxide 10x9; 10x10; 16x12, av. .36x.31 mm.

Feldspar 40x9; 40x7; 42x4, av. 1.22x.20 mm.
Augite 120x120; 85x75; 102x70, av. 3.07x2.65 mm.

Sp. 15736. Hole 13 at 171 feet from surface. Green mica after olivine; similar to 15735; feldspar extinction angles 6°-0°w26°-19°; 40°-42°; 25°-21°w41°-41°.

Sp. 15737. Hole 13A at 245 feet from surface. Poikilitic; greened olivine; low angled feldspar.

Sp. 15738. Hole 13A at 256 feet from surface. Pretty thoroughly changed to prehnite.

Sp. 15740. Hole 13 at 183 feet from surface. Fine grained; somewhat amygdaloidal.

Grain
Iron oxide 7x10; 7x8; 9x10, av. .23x.28 mm.
Feldspar 20x6; 24x7; 35x5, av. .79x.18 mm.
Augite 14x14; 15x10; 32x30, av. .61x.54 mm.

Sp. 15741. Hole 13 at 184 feet from surface. Microlitic, porphyritic.

Grain
Iron oxide 11x9; 11x7; 9x8, av. .31x.22 mm.
Feldspar phenocrysts 10x2; 14x4; 31x5, av. .55x.11 mm., smaller sized 2-3x0.1.
Augite 0.

(498)
184-229; (Ss. 15742-5). Melaphyre, feldspathic ophite (43) (541)

Sp. 15742. Hole 13 at 189 feet from surface. Amygdaloidal; slightly microlitic; much decomposed olivine; andesite.

Grain
Iron oxide 7x8; 7x8; 7x8, av. .21x.24 mm.
Feldspar 18x4; 27x3; 24x2, av. .69x.09 mm.
Augite 12x2; 12x6; 20x15, av. .44x.23 mm.

Sp. 15743. Hole 13 at 210 feet from surface. Coarser with symmetrical vein of calcite and quartz filling.

Grain
Iron oxide 9x7; 12x5; 12x5, av. .33x.17 mm.
Feldspar 25x4; 24x3; 29x3, av. .78x.10 mm.
Augite 25x10; 33x17; 18x14, av. .76x.41 mm.

There is a finer grain near the crack filled by the vein, which must be contemporaneous like an amygdaloid. Near the crack the augite is only 8x1, the feldspar 6x2.

Sp. 15744. Hole 13 at 222 feet from surface. Poikilitic.

Grain
Iron oxide 14x7; 12x11; 16x10, av. .52x.28 mm.
Feldspar 21x3; 25x4; 32x5, av. .78x.12 mm.
Augite 70x55; 80x47; 65x40, av. 2.15x1.42 mm.

Sp. 15745. Hole 13 at 229 feet from surface. Microlitic; almost glomeroporphyritic but of the type common near bottom of flows; fairly large olivines; andesite feldspar.

Grain
Olivine 6x9; 5x7; 13x22, av. .24x.38 mm.
Feldspar 25x12; 31x8; 24x6, av. .80x.26 mm.

229-230; (Ss. 157646). Sandstone, basic, associated with (1) (542)

clay veins running into hanging and foot. This or the bed at 125 feet may represent Marvine's slaty sandstone, No. 9; at least either of them is in about the right position for it, if the Minong conglomerate is the same as the Kearsarge conglomerate—for they would be 441 feet respectively 542 feet below.

If we depend on the coarse phenocrysts of the bed above the upper bed at 125 feet is the best match, and a number of sediments come shortly below the Wolverine. Compare Central Mine section (56) and (59) (Fig. 33), or 50 and 56, or also Manitou Frontenac (71) and (78) (Fig. 29).

Sp. 15746. Hole 13 at 230 feet from surface. Basic sediment like that at 125-126 feet; granules of augite, microlitic glass; feldspar; magnetite; calcareous cement. Margin 230.

230-252; (Ss. 15747-51). MELAPHYRE, amygdaloidal, fine (21) (563) grained; red, with clay veins from the top and the bottom; brecciated and prehnitic. Seems to be of the porphyrite type.

Sp. 15747. Hole 13 at 232 feet from surface. Microlitic porphyrite in contact with clasolite; much like 15745.

Grain

Curious alteration of olivine 20x10?

Feldspar 33x11; 12x6; 36x7, av. .81x.24 mm.

Sp. 15748. Hole 13 at 233 feet from surface. Looks like glomeroporphyrite in contact with sediment; low angles. This glomeroporphyrite is something like Huginnin porphyrite and Minong trap. Compare also beds 82 to 112 in the Central Mine section above mentioned, and 10 to 59 of the Torch Lake section (Fig. 38).

Sp. 15749. Hole 13 at 236 feet from surface. Microlitic porphyrite in contact with sediment.

Grain

Olivine 14x12; 12x10; 15x11, av. .41x.33 mm.

Feldspar 45x6; 48x15; 28x3, av. 2.21x.24 mm.

Sp. 15750. Hole 13 at 245 feet from surface. Very little augite; much low angled andesite; feldspar; extinctions often near 0° but up to 22°-11°; much olivine.

Grain

Olivine 10x11; 13x9; 8x6, av. .31x.26 mm.

Feldspar 23x6; 27x9; 44x6, av. .94x.21 mm.

Augite 13x7; 7x4; 6x7, av. .26x.18 mm.

Sp. 15751. Hole 13 at 252 feet from surface. Very prehnitic; fragments of porphyritic microlitic amygdaloid. At margin 252 feet.

252-342; (Ss. 15752-61). MELAPHYRE, ophite; feldspathic (87) (650)

Sp. 15752. Hole 13 at 257 feet from surface. Much decomposed; not very much augite; feldspar inclined to vary in size, low angled; it is characteristic of the poikilitic or ophitic texture here that the augite is badly cut up. This group of feldspathic ophites between conglomerates 9 and 8 is quite persistent on Keweenaw Point.

Grain

Olivine 18x15; 9x9; 11x11, av. .38x.35 mm.

Feldspar 12x4; 28x7; 22x10, av. .62x.21 mm.

Augite 17x14; 22x14; 30x12, av. .69x.40 mm.

Sp. 15753. Hole 13 at 262½ feet from surface. Similar poikilitic patches of augite, but feldspars very predominant.

Grain

Olivine 9x6; 13x12; 8x7, av. .30x.25 mm.

Feldspar 35x4; 35x11; 20x3, av. .90x.18 mm.

Augite 70x45; 46x45; 46x34, av. 1.62x1.24 mm.

Sp. 25754. Hole 13 at 271 feet from surface. More markedly poikilitic; feldspar extinctions 28°-12°w36°-30°; 17°-19°; 21°-16°w43°-36°.

Grain

Olivine 26x20; 11x10; 15x8, av. .52x.38 mm.

Feldspar 24x6; 24x3; 32x7, av. .80x.16 mm.

Augite with naked eye 2-3 mm.; 50x30; 80x65; 50x40, av. 1.80x1.35.

Sp. 15755. Hole 13 at 275 feet from surface. Similar to 15754, coarser; the feldspar in the patches is smaller than that between them; extinction angles 25°-13°; 49°-42°; 21°-8°w31°-31°.

Grain

Olivine 10x9; 5x7; 5x10, av. .20x.26 mm.

Feldspar 24x6; 27x5; 26x8, av. .77x.19 mm.

Augite with naked eye 3 mm.; 83x70; 80x56; 120x60, av. 2.83x1.86 mm.

Sp. 15756. Hole 13 at 299 feet from surface. More augitic; feldspar extinction angles 16°w40°-38°; 19°-16°w40°-41°.

Grain

Olivine 11x11; 15x8; 10x8; 7

Feldspar 42x11; 24x6; 30x5, av. .96x.22 mm.

Augite with naked eye 3+?; 105x75; 110x85; 160x72, av. 3.75x2.32 mm.

Sp. 15757. Hole 13 at 314 feet from surface. Similar to 15756 feldspar extinction angles 14°-20°w43°-44°.

Grain

Olivine 11x9; 17x13; 13x11, av. .41x.33 mm.

Feldspar 35x7; 24x6; 35x5, av. .94x.18 mm.

Augite with naked eye 4 mm.; 100x100; 110x100; 110x55, av. 3.20x2.55 mm.

Sp. 15758. Hole 13 at 323 feet from surface. Similar to 15757 feldspar extinction angles 19°-13°w44°-40°.

Grain

Olivine 25x21; 14x11; 14x13, av. .53x.45 mm.

Feldspar 27x12; 36x10; 22x6, av. .85x.28 mm.

Augite 77x70; 80x57; 120x70, av. 2.77x1.97 mm.

Sp. 15759. Hole 13 at 333 feet from surface. Feldspar extinction angles 23°-19°w43°-38°.

Grain

Olivine 5x14; 9x10; 15x6, av. .29x.30 mm.

Feldspar 33x5; 35x5; 36x9, av. 1.04x.19 mm.

Augite with naked eye 1-2 mm.; 27x22; 27x20; 57x30, av. 1.11x0.72 mm.

		(650)
342-349; (Ss. 15761-2). MELAPHYRE, amygdaloidal	(7)	(657)

Sp. 15761. Hole 13 at 342 feet from surface. Porphyritic much decomposed amygdaloid.

Grain

Olivine 13x14

Feldspar 15x3; 15x4; 14x4, av. .44x.11 mm.

Augite 12x6; 9x7; 12x7, av. .33x.20 mm.

Sp. 15762. Hole 13 at 349 feet from surface. There is a bottom amygdaloid, very black; very fine grained microlitic, feldspar extinction 20°, 33°, 28°. Margin at 347½.

Grain

Feldspar 18x4; 9x3; 17x5, av. .44x.12.

Beside this there is the top of the next flow, more feldspathic,—the feldspar so decomposed that its extinctions are doubtfully representative 14°-10°; 15°; 8°-0°; 12°-2° somewhat agglomerated grains 19x6; 30x10; 16x7.

349-359. (S. 15763). MELAPHYRE, amygdaloidal with prehnite (10) (667)

Sp. 15763. Hole 13 at 359 feet from surface. Microlitic, porphyritic with prehnite.

Grain

Olivine 7x7; 10x10; 32x17, av. .49x.34 mm.

Feldspar 24x4; 12x3; 15x3, av. .51x.10 mm.

359-447.5; (Ss. 15764-72). MELAPHYRE, ophite; amygdaloidal (86) (753) for the first 8 or 9 feet. All along in this flow there is not a clearly marked tendency to glomeroporphyritic character or separation of feldspar into two sizes.

Sp. 15764. Hole 13 at 364 feet from surface. Chalcedonic amygdaloid; almost glomeroporphyritic; very feldspathic.

Grain

Olivine 12x11; 29x17; 17x10, av. .58x.38

Feldspar 13x6; 20x7; 20x3, av. .63x.16

Augite 7x3; 8x5; 8x6, av. .23x.14.

Sp. 15765. Hole 13 at 370 feet from surface. More augite but still very little; low angled; feldspar extinctions 9°-7° etc.

Grain

Olivine 15x14; 30x18; 25x18, av. .70x.50 mm.

Feldspar 37x8; 25x9; 38x9, av. 1.00x.26 mm.

Augite 30x30; 50x16; 37x23, av. 1.17x.69 mm.

Sp. 15766. Hole 13 at 382 feet from surface. Usual poikilitic type; feldspar extinctions 22°-24°w27°-30°w40°; 23°-0° and 43°-37°; 38°.

Grain

Olivine 18x9; 16x9; 20x10, av. .54x.28 mm.

Feldspar 40x5; 40x13; 30x8, av. 1.10x.26 mm.

Augite 70x60; 50x30; 55x30, av. 1.75x1.20 mm.

Sp. 15767. Hole 13 at 403 feet from surface. Usual poikilitic type, feldspar extinctions slightly varying in concentric zones alternating more or less; extinction angles 26°-26°w42°-40°; 11°-10°[1]w38°-35°.

Grain

Olivine 11x9; 18x14; 14x10, av. .43x.33

Feldspar 50x15; 38x8; 26x10, av. 1.14x.35

Augite 90x55; 75x70; 80x80, av. 2.45x2.05.

Sp. 15768. Hole 13 at 410 feet from surface. Usual poikilitic type; extinction angles 29°-21°w33°; 21°-19°w45°; 30°-16°w46°-31°; 28°-25°w37°-34°; 25°-44° w11°-46° (varying in zones).

Grain

Olivine 20x12; 30x19; 20x18, av. .70x.49 mm.

Feldspar 38x20; 20x8; 25x7, av. .83x.35 mm.

Augite 45x40; 50x35; 70x45, av. 1.65x1.20 mm.

Sp. 15769. Hole 13 at 420 feet from surface. Usual poikilitic type; feldspar extinctions 45°-42°w13° and 32°-29, 18°-19°w41°-42°.

Grain

Olivine 15x14; 15x15; 10x10, av. .40x.39 mm.

Feldspar 30x8; 31x8; 34x12, av. .95x.28 mm.

Augite 74x40; 50x55; 80x72, av. 2.04x1.67 mm.

Sp. 15770. Hole 14 at 426 feet from bed rock surface. Usual poikilitic type; much feldspar still; a coarse part has more olivine and augite more by itself; feld-

[1]This 10° extinction is somewhat more in zones toward the center but alternates somewhat.

spar extinctions 28°-28°w?46°-37°; 34-36w39. In the basic coarse spot which may be doleritic there is more olivine and the feldspar is not so much enclosed in the augite. The feldspar extinctions are 17°w35°-30°; 22°-17°w41°-42°; 18°w35°-18°; 0°-13°.

Grain

Olivine 11x10; 14x10; 10x10; 20x21; 23x23; 22x15, av. .35x.30 and .65x.59 mm.

Feldspar 28x6; 31x9; 30x5; 45x7; 43x7; 38x7, av. 1.1x.2 mm.

Augite 60x45; 30x25; 35x30; 70x30; 150x50; 60x50, av. 1.25x1.00 and 2.80x 1.30 mm.

Sp. 15771. Hole 13 at 438 feet from bed rock surface. Finer grained amygdules in small interstices, patchy; feldspar extinctions 10°-17°w32°-35°.

Grain

Olivine 8x17; 10x7; 21x22, av. .39x.46 mm.

Feldspar 16x6; 25x10; 23x8, av. .64x.24 mm.

Augite 10x10; 12x12; 25x15, av. .47x.37 mm.

Sp. 15772. Hole 13 at 447 feet from bed rock surface. Feldspar seriate, but beginning to be hiatal; extinctions 8°-12°w35°-34°; chloritic amygdules.

Grain

Olivine 12x7; 13x10; 25x20, av. .50x.37 mm.

Feldspar 22x7; 24x9; 17x5, av. .63x.21; smaller one 7x2; 15x3; 10x2, av. .32 x.07 mm.

Augite 11x8; 13x8; 10x6, av. .34x.22 mm.

447.5-503; (Ss. 15773-9). MELAPHYRE, porphyrite; has a (44) 797 peculiar character microscopically, which we find again in the bed at the top of No. XIV; red; fine grained; laumontitic with chlorite and calcite; very feldspathic, with little augite visible, even under the microscope. Compare Central Mine beds 97-112. This flow has the very rare feature of a tendency to a double crop of augite as well as olivine and feldspar.

With this bed we pass to the record of drill hole No. XIV. If we compute where, in No. XIII, the top bed of No. XIV would be, with the dip that we have hitherto used, we find that it would correspond to No. XIII, 406 feet, right in the middle of a big ophite, whereas as a matter of fact the top of No. XIV lies under and to the north of an ophite bluff, and begins in beds like those at the bottom of No. XIII as already stated. There is therefore little doubt that the top of No. XIV corresponds to beds near the bottom of No. XIII. The exact correlation is uncertain, the range being between No. XIII, 503 feet, and No. XIII, 448 feet, with No. XIV, 11 feet. The correlation may possibly be No. XIII, 493 feet, to No. XIV, 22 feet, an intermediate and otherwise most plausible correlation. This corresponds to a dip of 16° 40′ here. If this steeper dip were due to a fault, it would mean that No. XIV was on the up-throw side, and the bottom of No. XIII on the down-throw side, but there is no reason to think that there is any such fault but rather to believe that this is the normally increasing true dip. *Consequently for No. XIV we use the factor 0.0438, to reduce from* VERTICAL *width along hole to true* THICKNESS.

For the next flow we have, from No. XIII, 447.5 to 493 feet, already given, 45.5 feet, lapping over on the first 22 feet of No. XIV.

Sp. 15773. Hole 13 at 447½ feet from bed rock surface. Olivine is often bastite; more amygdaloidal than 15772; augite granules in ground mass; porphyritic feldspar extinctions 0°-17°; 0°-20°; 0°-18°.

Grain

Olivine 10x9; 8x6; 8x7, av. .26x.22 mm.

Feldspar phenocrysts 24x7; 26x10; 20x9, av. .70x.26 mm.

Augite 2, 2, 1, 1, 4x2, av. .05 mm.

Sp. 15774. Hole 13 at 450 feet from bed rock surface. Much olivine; feldspathic amygdaloidal; extinction angles 6°-12°; 10°; 8°-6°; 16°-11°.

Grain

Olivine 19x14; 9x8; 13x12, av. .41x.34 mm.

Feldspar phenocrysts 14x4; 18x6; 20x8, av. .52x.18 mm.

Augite 6x4; 6x6; 10x4, av. .22x.14 mm.

Sp. 15775. Hole 13 at 462 feet from bed rock surface. Augite granules in two sizes, this is rare!; feldspar not sharply separated; extinction angles 45°-16°; 13°-14°; 24°-16°; all along here much olivine and traces of a small generation.

Grain

Olivine 18x15; 25x13; 40x20

Feldspar 20x4; 18x2; 22x3; 30x5; 23x13; 25x9, av. .6x.2

Augite phenocrysts 30x11; 7x7; 8x7; 10x8, av. .4x.2.

Sp. 15776. Hole 13 at 473 feet from bed rock surface. Microlitic porphyrite with augite granules, two sizes of not widely separated feldspar; finer grained than Sp. 15775.

Grain

Olivine 7x10; 7x12; 13x16, av. .27x.38 mm.

Feldspar larger 28x9; 22x7; 30x7, av. .70x.23 mm.; smaller 8x3.

Augite 4x4; 7x6; 4x2, av. .15x.12 mm.

Sp. 15777. Hole 13 at 492 feet from bed rock surface. Porphyritic microlitic; much decomposed.

Grain

Olivine 16x13; smaller generation of olivine 8x7; 5x2

Feldspar larger 33x11; 30x10; 20x5; smaller about 4 or 5x1; av. .83x.26

Augite 3x1; 2x2; 2, 1.

Sp. 15778. Hole 13 at 500 feet from bed rock surface. Calcite veins; amygdules; basic feldspar; extinction angles 23°-32°w18°-11°; 25°-23°w45°-36°.

Grain

Olivine 10x5; 15x12; 15x10; 10x13

Feldspar phenocrysts 33x7; 42x15; 23x7, av. .98x.29 mm.

Augite 6x4; 5x2; 4x3, av. .15x.09 mm.

Sp. 15779. Hole 13 at 503 feet from bed rock surface. Feldspar in two sizes; augite in grains; glomeroporphyritic texture not marked; extinction angles 32°-30°w15°; 20°-32°w17°.

Grain

Olivine 15x10; 15x14; 12x8, av. .42x.32 mm.

Feldspar phenocrysts 33x12; 33x14; 33x10, av. .99x.36 mm.

Augite 6x4; 5x5; 7x5; 10x6, av. .23x.16 mm.

22-138; (Ss. 15780-9). MELAPHYRE, porphyrite; the last 10 (111) (908) feet of No. XIII are equivalent to this; at 30-33 feet was a seam of prehnite with numerous *copper* crystals; at 90 feet and again at 123 feet a chloritic seam with *copper* and calcite.

This is also of the porphyritic type with a tendency to idiomorphic augite and two generations of feldspar always, augite at times. Compare the beds in holes 4 and 6 of the Central Mine section 97-112.

Sp. 15780. Hole 14 at 11 feet from bed rock surface. Very prehnitic; microlitic porphyritic; augite granules; extra feldspathic with extinction angles 6°-10°w10°-15°; phenocryst 7°-12°w-20°.

Grain

Olivine 4? ?

Iron oxide 2; 3; 2

Feldspar 23x15; 30x13; 22x10; av. .75x.38 mm.
Augite 5x4; 3x2; 4x3, av. .12x.09 mm.

Sp. 15781. Hole 14 at 15 feet from bed rock surface. Glomeroporphyritic feldspar; extinction angles 9°-8°w21°; idiomorphic augite granules; sp. 15749 is like it.

Grain
Iron oxide ?2; 3; 4
Feldspar phenocrysts 35x10; smaller 11x2; 7x1; 10x1, av. .28x.04 mm.
Augite 8x9; 1x1; 10x10; 15x10, av. .28x.25 mm.

Sp. 15782. Hole 14 at 22 feet from surface. Glomeroporphyritic; augite in grains; low angled feldspar.

Grain
Olivine 7x7? 9x8; 6x6, av. .22x.21 mm.
Iron oxide 9x9; 12x10; 10x5, av. .31x.24 mm.
Feldspar phenocrysts 35x15; smaller size 12x1; 12x1, av. .59x.17 mm.
Augite 12x8; 22x11; 11x5, av. .45x.24 mm

Sp. 15783. Hole 14 at 29 feet from bed rock surface. Feldspar coarser low angled; augite grains; red and green olivine.

Grain
Olivine 10x8; 6x6; 15x8, av. .31x.22 mm.
Iron oxide 17x15; 4x4, av. .35x.31 mm.
Feldspar 52x12; 20x10; 15x15, av. .87x.37 mm.
Augite 10x8; 20x10; 15x15, av. .45x.33 mm.

Sp. 15784. Hole 14 at 46 feet from bed rock surface. Augite still in grains. Glomeroporphyritic; feldspar appears more basic; very little olivine; extinction angles 42°-39°w7°; 44°-41°w19°; w35°-57°; 31°-17°w50°; 34°-46°; 19°-28°w.49°.

Grain
Olivine 8x7; 5x4; 4x4, av. .17x.15 mm.
Feldspar 35x15; 15x2; 20x2, av. .70x.19 mm.
Augite 25x20; 12x8; 14x5, av. .51x.33 mm.

This section also shows very well a feldspar cut nearly parallel to m (010).

Sp. 15785. Hole 14 at 65 feet from surface. Basic feldspar with extinction 45°-45°w60°-46°; 32°-35°w47°-47°; augite in grains; greened olivine.

Grain
Olivine 12x9; 10x8; 9x6, av. .31x.23 mm.
Feldspar phenocrysts 42x12; 30x11, av. 1.2x.38 mm.; smaller 10x1
Augite 19x19; 16x13; 20x17, av. .55x.49 mm.

Sp. 15786. Hole 14 at 90 feet from bed rock surface. Similar to 15785; feldspar extinction angles 45°-45° and 30°-25°; 26°-27°; 37°.

Grain
Olivine 5x4; 10x9; 11x11, av. .26x.24 mm.
Feldspar 33x11; 30x11; 8x2, av. .71x.24 mm.
Augite 11x9; 17x10; 13x13, av. .41x.32 mm.

Sp. 15787. Hole 14 at 120 feet from bed rock surface. Similar to 15786; 21°-22°w33°-37°; 13°-16°w35°-41°; 28°-33°; 30°-6°w50°-38°.

Grain
Olivine 9x8; 8x6; 10x8; 15x9, av. .35x.25 mm.
Feldspar 43x11; 30x17; 27x10, av. 1.00x.38 mm.
Augite 15x10; 15x14; 20x8, av. .50x.32 mm.

Sp. 15788. Hole 14 at 123 feet from bed rock surface. Similar; augite fine; much decomposed.

Grain

Olivine 9x8; 15x8, av. .4x.31 mm.

Iron oxide 7

Feldspar 57x30? 28x12; 20x5, av. 1.05x.47 mm.

Augite 20x10; 9x9; 12x7, av. .41x.26 mm.

Sp. 15789. Hole 14 at 138 feet from surface. Much decomposed; similar to 15788; in contact with very prehnitic belt; porphyritic; very feldspathic. Distance from margin 1 ft.

A. Appears to show the decomposed top of a flow with worn off fragments or ash embedded in a fine grained altered mud.

Feldspar 30x5.

B. Has well defined structure, but the feldspar is all changed to prehnite. It is in two generations and the augite is more idiomorphic than often.

Grain

Olivine?

Iron oxide 4?

Feldspar phenocrysts 17x8; 60; 55; 10; 10

Augite 10; 7; 13; 5; 8; 7.

139-200; (Ss. 15790-7). MELAPHYRE, ophite; feldspathic, 58 (966)

first 9 feet amygdaloidal; toward the bottom, veins with prehnite and *copper*.

Sp. 15790. Hole 14 at 140 feet from surface. Large phenocrysts of feldspar much changed to prehnite; reddened amygdaloidal; porphyritic feldspathic; scanty idiomorphic augite.

Grain

Feldspar phenocrysts 30x5; 41x8; 44x11, av. 1.15x.24 mm.

Augite 5x2; 6x5; 7x7, av. .18x.14 mm.

Sp. 15791. Hole 14 at 150 feet from surface. Very feldspathic with phenocrysts; augite granules; rather low angled feldspar extinctions.

Grain

Olivine 16x11; 13x11; 12x7, av. .41x.28 mm.

Feldspar phenocrysts 40x17; 25x12; 31x30, av. .96x.59 mm.

Augite 14x13; 10x10; 8x7, av. .32x.30 mm.

Sp. 15792. Hole 14 at 159 feet from surface. Poikilitic; low angled feldspar; extinction angles 8°-8°w0°.

Grain

Olivine 21x15; 11x9; 13x12, av. .45x.36 mm.

Feldspar 27x7; 40x8; 32x10, av. .99x.25 mm.

Augite 60x57; 72x40; 50x36, av. 1.82x1.33 mm.

Sp. 15793. Hole 14 at 170 feet from surface. Poikilitic; feldspar extinction angles 42°-48°w14°-14°; 43°-49°w12°.

Grain

Olivine 13x13; 17x16; 10x10, av. .40x.49 mm.

Iron oxide 15x15

Feldspar 34x11; 23x10; 55x20, av. 1.12x.41 mm.

Augite with naked eye 2-3 mm.; 80x56; 65x60; 55x52, av. 2.01x1.67 mm.

Sp. 15794. Hole 14 at 179 feet from surface. Poikilitic; feldspar extinction angles -0°-12°-32°w14°-24°; 30°-31°+w10°-8°; 30°-45°w16°-21°.

Grain

Olivine 13x11; 12x12; 22x22, av. .37x.55 mm.

Feldspar 25x6; 40x13; 33x13, av. .98x.32 mm.

Augite 85x65; 80x60; 85x85, av. 2.50x2.10 mm.

Sp. 15795. Hole 14 at 189 feet from surface. Microlitic porphyrite; reddened olivine (iddingsite); the microlites are low angled and forked in the ground mass.

Grain

Olivine 8x7; 22x20; 10x9, av. .40x.36 mm.
Feldspar phenocrysts 15x2; 33x9; 40x8, av. .88x.19 mm.
Augite less than 0.5.

Sp. 15796. Hole 14 at 199 feet from surface. Feldspathic; partly idiomorphic augite grains.

Grain

Olivine 10x9; 10x9; 15x12, av. .35x.30 mm.
Feldspar 22x7; 31x9; 33x3, av. .86x.19 mm.
Augite 16x13; 23x4; 25x20, av. .64x.37 mm.

Sp. 15797. Hole 14 at 200 feet from surface. Microlitic; porphyritic.

Grain

Olivine 7x6; 12x10; 7x6; 7x8; 7x8, av. .33x.31 mm.
Feldspar 19x7; 28x4; 11x3, av. .58x.14 mm.
Augite?

200-202; (S. 15798). SANDSTONE, basic; with amygdaloidal 2 (968)

fragments. This is hardly in the right place for Marvine's conglomerate No. 8. Compare rather Central Mine 96. There are a number of very minor sedimentaries between Marvine's conglomerate 8 and 9. (See Fig. 33).

Sp. 15798. Hole 14 at 202 feet from surface. Section shows contact with basic sediment enclosing fragments of amygdaloid with low angled feldspar; much olivine in sediment.

202-367; (Ss. 15799-810). MELAPHYRE, ophite; amygdaloidal the (159) (1127)

first 9 feet; seamed near 299 feet; a typical coarse ophite which helps to form the northwest front of the island, and is quite persistent along the strike. Compare Central Mine beds 107-116.

Sp. 15799. Hole 14 at 203 feet from surface. Poikilitic augite; also somewhat glomeroporphyritic low angled feldspar.

Grain

Olivine 7; 12x7; 6x5; 5
Feldspar 14x3; 20x8; 25x22, av. .59x.33 mm.
Augite 17x15; 33x20; 33x17, av. .83x.52 mm.

The variation in grain is particularly well shown and is illustrated by Figures 14, 15 and 18 of the Isle Royale Report, Vol. VI.

Sp. 15800. Hole 14 at 212 feet from surface. Poikilitic; low angled feldspar 0°-12° etc.

Grain

Olivine 6x6; 15x10; 10
Feldspar 16x4; 26x5; 32x10, av. .74x.19 mm.
Augite 48x35; 57x40; 62x22, av. 1.67x.97 mm.

Sp. 15801. Hole 229 feet from surface. Poikilitic; feldspar extinction angles 24°; 19°; 17°-10°w31°-32°, in a Baveno twin 23°-14° with 37°-15°.

Grain

Olivine 11x8; 11x7; 10x10, av. .31x.25 mm.
Feldspar 21x6; 28x5; 40x5, av. .89x.16 mm.
Augite 62x42; 90x65; 50x40, av. 2.02x1.47 mm.

Sp. 15802. Hole 14 at 266 feet from surface. Not glomeroporphyritic; feldspar extinctions 24°-16°; 13°-9°w40°-40°; 20°-17°w42°-38°w16°?-11°; 11°-7°w35°-9°.

Grain

Olivine 19x15; 13x13; 13x10, av. .45x.38 mm.

Feldspar 11x4; 28x7; 24x5, av. .63x.16 mm.

Augite 220x340; 160x170; 175x240, av. 5.55x7.50 mm.

Sp. 15803. Hole 278 feet from surface. Poikilitic; feldspar extinction angles 0°-15°w22°-30°; 20°w31°-31°; 14°-2°w28°-19°.

Grain

Olivine 10x10; 16x15; 15x10, av. .41x.35 mm.

Feldspar 21x3; 27x8; 60x5 (nest), av. 1.07x.16 mm.

Augite 140x120; 100x90; 130x95, av. 3.70x3.05 mm.

Sp. 15804. Hole 14 at 294 feet from surface. Poikilitic; much decomposed; micaceous; this is from a peculiar seam a foot or two wide, perhaps originally an olivine band like that which occurs in the Palisade trap described by Volney Lewis.[1]

Olivine 20x17; 30x20; 14x11, av. .64x.48 mm.

Feldspar 12x1; 18x3; 42x7, av. .72x.11 mm.

Augite 230x190; 210x140; 120x80, av. 5.60x4.10 mm.

Sp. 15805. Hole 14 at 304 feet from bed rock surface. Poikilitic; feldspar extinction angles 29°-31°w18°; 20° to 24°-36°w37°-48°; 28°-33°; 19°-16°.

Grain

Olivine 16x15; 14x13; 18x17, av. .48x.45 mm.

Feldspar 33x8; 22x4; 34x8, av. .89x.20 mm.

Augite by naked eye 7 mm.; 140x130; 250x160; 205x140; 210x140, av. 6.04 x4.28 mm.

Sp. 15806. Hole 14 at 320 feet from bed rock surface. Nests of feldspar replacing poikilitic augite patches; extinction angles 20°-18°; 44°-37°w10°; 47°-38°w 22°-17°; 27°-35°w43°.

Grain

Olivine 10x9; 11x10; 19x18, av. .40x.37 mm.

Feldspar 25x12; 20x5; 15x8, av. .60x.25 mm.

Augite 180x120; 180x175; 130x90, av. 4.90x3.85 mm.

Sp. 15807. Hole 14 at 329 feet from bed rock surface. 15805 to 15808 are very similar; poikilitic; fresh olivine!; also much feldspar; extinction angles 15°-22°?w 44°-44°; 30°-38°.

Grain

Olivine 25x18; 15x15; 14x10, av. .54x.43 mm.

Iron oxide 18x17

Feldspar 22x5.5; 37x7; 37x12, av. .96x.24 mm.

Augite 155x120; 105x90; 85x85, av. 3.45x2.95 mm.

Sp. 15808. Hole 14 at 348 feet from bed rock surface. Similar; finer; feldspar slightly nested; extinction angles 11°-11°w40°-37°.

Grain

Olivine 16x12; 20x16; 9x6, av. .45x.34 mm.

Feldspar 13x5; 17x4; 32x10, av. .62x.19 mm.

Augite to naked eye 2-3 mm.; 90x45; 73x60; 80x72, av. 2.43x1.77 mm.

Sp. 15809. Hole 14 at 359 feet from surface. Augite more or less polysomatic finer grained; feldspar phenocrysts extinction angles 16°-15°w43°-42°.

Grain

Olivine 4x6; 6x6; 10x8, av. .20x.20 mm.

Feldspar 17x3; 20x4; 16x4, av. .43x.11 mm.

Augite 37x20; 40x35; 50x20, av. 1.27x.75 mm.

---

[1]Petrography of the New Igneous Rocks of New Jersey by J. Volney Lewis, Annual Report of the State Geologist, 1907, pp. 115, 127.

Sp. 15810. Hole 14 at 367 feet from surface. 27x8 olivine or enstatite? microlitic porphyritic; amygdaloid chloritic with quartz; low angled feldspars.

Grain

Olivine 3x3; 3x7; 4x4, av. .10x.14 mm.

Feldspar phenocrysts 16x7; 16x5; 13x7, av. .46x.19 mm.

Augite 0.

367-436; (Ss. 15811-9). The Huginnin porphyrite. This very (67) (1194) marked and peculiar bed has a fine grained red ground-mass, in which are large crystals of whitish feldspar, frequently about a fifth to a half of an inch long. It is not uniformly amygdaloidal, but has streaks of half-filled vesicles with chlorite and *copper* and prehnite and *copper* veins. It has distinct lines of flow and the upper 10 feet may be an independent flow. The prehnite and *copper* veins and laumontite seams occur throughout the bed to the bottom. This porphyrite outcrops in the bed of Huginnin Creek about 50 feet from the shore of Huginnin Cove and about 200 feet from the mouth of the creek; whence its name. Lying as it does, between two more resistant big sheets of ophite, and having sediment under it, but little is seen of it in spite of its very peculiar and easily marked character, for there is no flow just like it in the whole series. We do, however, catch another glimpse of it near the mouth of McCargoe Cove, about 500 paces north and 1,300 paces west of the southeast corner of Sec. 13, T. 66, R. 35, where it occurs with a similar environment. It seems to have caught Foster and Whitney's eyes. Fig. 5 of Plate VI, and Fig. 20, p. 140 of the Isle Royale Report, illustrate the grain.

There is a porphyritic bed under the Copper Point ophite at Mamainse which may possibly be correlated with this Huginnin Porphyrite.

Sp. 15811. Hole 14 at 370 feet from surface. Fine grained; very feldspathic; has finer and more ferruginous borders to amygdules.

Iron oxide 3x2; 2x4; 3x4

Feldspar 10x1; 10x2; 8x15.

Sp. 15812. Hole 14 at 373 feet from bed rock surface. Contact with fine grained sediment with similar rock on each side, or is the sediment a mere clasolite?

Grain

Olivine 0?

Iron oxide 3x0.2

Feldspar 9x1; 8x3; 9x15, av. .26x.19 mm.

Augite 0?

Sp. 15813. Hole 14 at 379 feet from surface. Contact with a sediment; low extinction angle, plagioclase.

Grain

Olivine 0?

Iron oxide 2x5; 2x4; 2x3, av. .06x.12 mm.

Feldspar 12x1; 11x1; 11x2, av. .34x.04 mm.

Augite 0?

Sp. 15814. Hole 14 at 379 feet from surface. Contact with a clasolitic vein; feldspathic trap.

Grain

Feldspar 9x2; 10x2; 8x2, av. .27x.06 mm.

Sp. 15815. Hole 14 at 384 feet from bed rock surface. Very feldspathic, (low angled); no olivine? augite only in idiomorphic granules.

Grain

Olivine 0?

Feldspar 16x2; 23x4; 11x2, av. .50x.08 mm.

Augite 7x3; 2x3; 3x1.5, av. .12x.07 mm.

Sp. 15816. Hole 14 at 393 feet from bed rock surface. Feldspar brotocrysts i. e., large corroded porphyritic crystals 180x100; low angled feldspar; small augite granules; no olivine.

Grain

Feldspar 15x2; 12x1; 15x1; 16x1, av. .40x.04 mm.

Augite 2, 3, 4, 11x1, 8x2, 3x2.

Sp. 15817. Hole 14 at 416 feet from bed rock surface. Similar to 15816. The large feldspar phenocrysts look like orthoclase and are 80x35 and 80x42 and hardly twinned; low angled extinctions; micaceous alteration.

Grain

Iron oxide 5x6; 4x5; 4x10, av. .13x.21 mm.

Feldspar 9x1.5; 11x1; 13x2, av. .33x.04 mm.

Augite 2; 2; 3; 5x.6; 8x1.5; 4x2.

Sp. 15818. Hole 14 at 435 feet from bed rock surface. 11-0; 16; low angled.

Grain

Olivine 0

Iron oxide 4x3; 6x1; 3x2, av. .13x.06 mm.

Feldspar phenocrysts 7x4mm. with naked eye or 40x28; 205x147; smaller 12x4; 8x1; 7x1; 12x1, av. .30x.07 mm.

Augite 8x1; 6x1; 5x2, av. .19x.04 mm.

Sp. 15819. Hole 14 at 436 feet from bed rock surface. Feldspathic often glomeroporphyritic; porphyritic and other feldspar low angled; microlitic porphyritic; much olivine; augite granules; low angled feldspar.

Grain

Olivine 22x15; 13x7; 8x6

Feldspar 65x20; 30x12; 30x6, av. 1.25x.38 mm.

Augite 3x2; 3x1; 2x1, av. .08x.04 mm.

436-440; (Ss. 158-20). Ash, brecciated. The microscope (4) (1198)

shows conchoidal glass forms in this rock. It is suggestive in this connection that the bed above is salic such as is more likely to come with ash-producing explosions.

Sp. 15820. Hole 14 at 438 feet from bed rock surface. Epidote and quartz amygdules, also olivine plagioclase aggregate; margin of porphyrite in contact with prehnitic belt; ash fragments with conchoidal outlines.

Grain

Olivine 13x7; 10x8; 14x11, av. .37x.26 mm.

Feldspar phenocrysts 18x7 microlites at 4x1 and less

Augite 8x5.

There are what look like aragonite fibres here.

440-605; (Ss. 15821-34). Melaphyre, ophite. This big (158) (1356)

flow rivals the "backbone" greenstone. It appears to be remarkably olivinitic and to have more iron than the latter. (Compare beds above the Isle Royale Lode). It is so much finer grained toward the bottom of the hole that we must infer that there are not more than 10 more feet of it. This big ophite being beneath the porphyrite at Huginnin Cove, will be expected to make the front range of the northwest coast. It seems to me there is a tendency for salic beds like the Huginnin Porphyrite to come after a very big ophite as a sort of skimming. Now along this coast three holes were put down, Nos. XII, XV, and XVI. They are all about on the same line of strike, No. XV about 10 feet lower than No. XVI and No. XII about half-way between them in position. The samples from No. XII were thrown into confusion by fire, but we have a few that are well authenticated, from the bottom beds and from some other characteristic beds, and we have Stockly's record.

We find in the field that drill hole No. XV lies on the east or upthrown side of the fault already mentioned, No. XVI on the west; No. XII is very near the break, but apparently also to the east of it. On comparing records, however, we find that No. XII is much more nearly in accord with No. XVI, at least in the lower part indicating either that the fault is east of that part of No. XII or that the character of the upthrow has changed. Field observations above No. XV show a series of amygdaloids capped by an ophite under which we get a good contact, and a dip 18° to N, 26° W. This contact is about 87 feet above the lake, on a slope whose angle is 28°, while No. XV is only a little above the lake and close to it.

Fig. 12 of the Isle Royale Report shows the section at No. XV, and shows that the top of No. XV appears to be something over 100 feet lower than the big ophite at the bottom of No. XIV. If, therefore, we suppose that the record of No. XVI begins where that of No. XIV leaves off, we shall be in harmony with the observed dips, and not be in danger of leaving out more than some 50 feet of amygdaloids such as are exposed above the top of No. XV. It should be said, however, that the nearer the top we compare No. XV and No. XVI the less faulting there seems to be between them. But the records of the upper parts are not very clear, and I fear the samples were not carefully arranged in the boxes.

There is another difficulty and uncertainty attending the construction of this end of our column. We have seen that the dip seems to be increasing faster and faster. Now we have no outcrops nor drill holes farther to the north to guide us as to the rate at which this increase progresses as we go down or to the north, and the north side of the Isle may be upturned close to a large fault. Consequently the amount of allowance for reduction from vertical width to thickness is much more uncertain. We have to guide us only dips measured on drill cores which are not very safe guides, and also dips exposed on Amygdaloid Island, and on adjacent islands, toward the other end of the Isle Royale, which correspond to these lower beds. Both these dips and the dips on the drill cores agree in indicating an increase over the dips observed higher in the series, i. e., toward the southeast. In such a case the allowances for dip, and the dips assumed, are matters of general judgment rather than of precise calculation. We will continue to assume the 18° dip down to the first conglomerate at No. XVI, 437 feet, *which involves taking off 1-20 to reduce* from VERTICAL *width* to THICKNESS.

We base our description here on record of No. XVI, as it is the deepest hole from which we have a full set of cores.

Sp. 15821. Hole 14 at 440 feet from bed rock surface. Microlitic porphyrite; much olivine and apparently a younger generation; feldspar groups.

Grain

Ol vine phenocrysts 12x10; 15x6; 15x12; av. .42x.28 mm. smaller ones? 2, 3, 2;

Sp. 15822. Hole 14 at 449 feet from surface. Feldspar groups; no augite? very feldspathic; not very olivinitic; trichitic.

Grain

Olivine 3x7; 4x7; 5x6, ax. .12x.20.

Feldspar phenocrysts 29x16; 22x8; 30x9; .81x.33; smaller trichites 2 to 3 long.

Sp. 15823. Hole 14 at 462 feet from bed rock surface. Marked poikilitic; olivine nests; labradorite feldspar.

Grain

Olivine phenocrysts 13x10; 15x10; 16x14, av. .44x.34 mm.

Feldspar 18x5; 18x4; 14x2, av. .50x.11 mm.

Augite 57x52; 65x48; 40x43, av. 1.62x1.43 mm.

Sp. 15824. Hole 14 at 471 feet from bed rock surface. Olivine nests; labra-

dorite coarser; nested feldspar extinction angles 34°-34°w23°-24°; 36°-40°w21°-19°; 36°-22°; 32°-30°; 40°-30°; 41°-21°.

Grain

Olivine phenocrysts 23x10; 20x18; 18x13, av. .61x.41

Iron oxide 4x5; 4x7; 7x17, av. .15x.29

Feldspar phenocrysts 14x4; 18x6; 11x2; 12x1, av. .55x.13 mm.

Augite 65x55; 90x85; 85x57, av. 2.40x1.97 mm.

Sp. 15825. Hole 14 at 476 feet from surface. Green micaceous olivine; grain about 14 in 15 mm.; poikilitic augite, feldspar extinction 35°-36°w27°-20°; 39°-19°w14°-8°.

Grain

Olivine 22x13; 25x17; 32x20, av. .79x.50 mm.

Feldspar 16x5; 15x6; 15x3, av. .46x.14 mm.

Augite 100x95; 80x80; 100x70, av. 2.80x2.45 mm.

Sp. 15826. Hole 14 at 492 feet from surface. Poikilitic, coarser augite; about 5 in 20 mm.; feldspar extinction 36°-30°w25°-16°; 45°-45°w13°.

Grain

Olivine 23x18; 26x20; 20x16, av. .69x.54 mm.

Feldspar 22x11; 13x3; 18x7, av. .53x.21 mm.

Augite 85x80; 157x130; 140x75, av. 3.82x2.85.

Sp. 15827. Hole 14 at 514 feet from bed rock surface. Fresh olivine! poikilitic; coarser; augite has about 4 mottles in 20 mm., generally 2 feldspars in each mottle, extinction angles 32°-25°; 41°-45°w10°.

Grain

Olivine 10x7; 18x11; 14x14, av. .42x.32 mm.

Feldspar 16x6; 13x3; 19x6, av. .48x.15 mm.

Augite 180x90; 140x110; 130x100, av. 4.50x3.00 mm.

Sp. 15828. Hole 14 at 531 feet from bed rock surface. Zonal extinction angles larger at center; 7x1 is nearer the size of the feldspars enclosed in the augite mottles of which there are about 3½ in 20 mm.; ex. 30°-25°.

Grain

Olivine 52x30; 32x20; 25x23, av. 1.09x.73 mm.

Feldspar 20x5; 20x8; 20x5, av. .60x.18 mm.

Augite 220x185; 180x175; 180x140, av. 5.80x5.05 mm.

Sp. 15829. Hole 14 at 552 feet from bed rock surface. Poikilitic; finer grained than 15828; ex. 42°-32°w5°-15°; grain of augite very uncertain, mottles ? 4 to 20 mm.

Grain

Olivine 15x12; 44x27; 31x19, av. .90x58.

Feldspar 16x7; 20x5; 33x7, av. .69x.19

Augite 130x120; 180x160; 160x110, av. 3.70x3.90

Sp. 15830. Hole 14 at 568 feet from bed rock surface. About=15827; feldspar semi-poikilitic; most of them about 7-8x1; 4 mottles in 18 to 16 mm.; ex. 40°w 15°-27°; 40°-30°; 33°-22°.

Grain

Olivine 9x8; 17x16; 25x16; 26x23, av. .57x.48

Feldspar 28x7; 36x6; 12x5; 8x3; 16x2; 20x6, av. .60x.15

Augite 120x120; 130x110; 135x120; 120x100; 140x110; 140x120, av. .39x3.4.

Sp. 15831. Hole 14 at 580 feet from bed rock surface. Olivine altered to magnetite aggregate; poikilitic; 6 mottles to 18 mm.; ex. 47°-42°w-29°; 27°-23°w-35°.

Grain

Iron oxide 14x12; 19x18; 22x16, av. .55x.46

Feldspar 20x7; 15x7; 20x7, av. .55x.21

Augite 60x55; 67x60; 80x68, av. 2.07x1.83.

Sp. 15832. Hole 14 at 588 feet from bed rock surface. Poikilitic; finer; 8-20, 10°-3°w39°-19°.

Grain

Iron oxide 15x13; 18x10; 24x20, av. .57x.43

Feldspar 17x3; 17x4; 22x6, av. .56x.13

Augite 45x42; 64x37; 53x44, av. 1.62x1.23

Sp. 15833. Hole 14 at 593 feet from bed rock surface. The feldspars measured are semi-porphyritic, the extinctions are 4° to 8°-1°; 13° or 14° to 20°; 44°-42°w 18°; 31°-24°; 39°-28°; much iron in this flow, more than in "Greenstones." Cf. 15906-15918, also 15166.

Grain

Iron oxide 12x10; 22x7; 15x13; 11x9, av. .45x.29

Feldspar 22x8; 23x7; 16x4; 20x5, av. .61x.18

Augite 35x33; 50x40; 70x32, av. 1.55x1.05.

Sp. 15834. Hole 14 at 605 feet from bed rock surface. Ophitic augite in long prisms; 34°-31°; 35°-36°w28°; 44°-36°.

Grain

Feldspar 35x3; 24x5; 27x3, av. .76x.11

Augite 75x24; 40x23; 60x13; 42x24; av. 1.62x.63

(1356)

DRILL HOLE No. XVI

0-39; (Ss. 15835-7). MELAPHYRE, ophite; chloritic amygdules (38) (1394) at top of bed.

Sp. 15835. Hole 16 at 9 feet from bed rock surface. Very feldspathic augite tends to be in granules; moderate extinction angles 6°-7°; 11°; 7°-0°; 10°-8°.

Grain

Olivine 10x8; 13x10; 17x8, av. .40x.26 mm.

Feldspar 19x4; 26x7; 21x4, av. .66x.15 mm.

Augite 24x20; 20x10; 24x4, av. .68x.34 mm.

Sp. 15836. Hole 16 at 19 feet from bed rock surface. Much very basic feldspar, extinction angles 3°; 43°-38°; 19°-15°w36°-23°; 26°-29°w10°-16°; little olivine; poikilitic; augite may be taken too large.

Grain

Olivine 15x10; 12x11; 8x7, av. .35x.28 mm.

Iron oxide 19x13; 15x12; 18x11, av. .52x.36 mm.

Feldspar 27x5; 21x4; 32x7, av. .80x.16 mm.

Augite 40x35; 50x42; 35x12, av. 1.25x.89 mm.

Sp. 15837. Hole 16 at 34 feet from bed rock surface. Yellow green large olivine; poikilitic.

Grain

Olivine 13x11; 15x13; 17x12, av. .45x.36 mm.

Feldspar 23x6; 23x3; 20x6, av. .66x.15 mm.

Augite 48x43; 70x50; 110x45, av. 2.28x1.38 mm.

39-54; (Ss. 15838-40). MELAPHYRE; streak of green prehnitic (14) (1408) amygdaloid at top.

Sp. 15838. Hole 16 at 39 feet from bed rock surface. Porphyritic microlitic; with prehnite; feldspar decomposed; marginal; like 15843.

Grain

Feldspar phenocrysts 22x2; 21x4; 23x3, av. .66x.09 mm.

Sp. 15839. Hole 16 at 50 feet from bed rock surface. Much feldspar; low extinction angles 0°w11°-8°.

Grain

Olivine 11x8; 15x11; 8x8, av. .34x.27 mm.
Feldspar 19x4; 18x2; 25x5, av. .62x.11 mm.
Augite 20x9; 30x10; 17x7, av. .67x.26 mm.

54-81; (Ss. 15840-2). MELAPHYRE; red and amygdaloidal (26) (1434) for the first 6 to 8 feet, with calcite and laumontite (?) in amygdules.

Sp. 15840. Hole 16 at 54 feet from bed rock surface. Very dark red microlitic-porphyritic amygdaloid; calcite and laumontite generally.

Grain

Olivine 5x2; 6x4; 4x4, av. .15x.10 mm.
Feldspar phenocrysts 22x5; 14x2; 18x4, av. .54x.11 mm.
Augite 0?

Sp. 15841. Hole 16 at 70 feet from bed rock surface. Very low angled feldspar.

Grain

Olivine 7x5; 10x9; 11x10, av. .28x.24 mm.
Feldspar 24x6; 16x4; 25x4, av. .65x.14 mm.
Augite 30x20; 25x14; 17x12, av. .72x.46 mm.

Sp. 15842. Hole 16 at 72 feet from bed rock surface. Low angled feldspar.

Grain

Olivine 8x8; 11x8; 12x6, av. .31x.22 mm.
Feldspar 30x5; 25x3; 25x5, av. .80x.13 mm.
Augite 22x15; 27x13; 13x10, av. .52x.38 mm.

81-114; (Ss. 15843-7). MELAPHYRE, amygdaloidal; at the (31) (1465) top the bed is a green prehnitic amygdaloid like that at 39 feet, which I suppose to crop out under the lake. From 88-99 feet it is much broken and shattered and appears amygdaloidal.

Sp. 15843. Hole 16 at 81 feet from bed rock surface. Crops out under lake. Distance from margin 81.

Grain

Feldspar phenocrysts 16x2; 15x2; 18x3, av. .49x.07 mm.
Thickness at cross section 77.

Sp. 15844. Hole 16 at 86 feet from bed rock surface.

Grain

Olivine 22x17; 14x13; 14x10, av. .50x.40
Feldspar 22x4; 23x5; 20x5, av. .65x.14
Augite 10x10; 23x13; 22x10, av. .55x.33

114-153; (Ss. 15848-50). MELAPHYRE, feldspathic; intermediate (38) (1503) between porphyrite and ophite.

Sp. 15848. Hole 16 at 140 feet from bed rock surface. Very feldspathic; xenomorphic augite; feldspar extinction angles 42°-38°w13°; 34°-33°w19°-16°; 40°-38°w20°-18°.

Grain

Olivine 17x15; 13x10; 13x10, av. .53x.35 mm.
Feldspar 18x2; 16x3; 28x3, av. .62x.08 mm.
Augite 22x20; 32x30; 32x17, av. .86x.67 mm.

Sp. 15849. Hole 16 at 145 feet from bed rock surface. Slightly poikilitic; much feldspar; extinction angles 37°-32°w15°-0°; 31°-25°.

Grain

Olivine 10x8; 14x9; 9x8, av. .33x.25 mm.

Feldspar 21x2; 21x2; 20x6, av. .62x.10 mm.

Augite 50x50? 23x18; 33x20, av. 1.06x1.03 mm.

Sp. 15850. Hole 16 at 153 feet from bed rock surface. Porphyritic; fine grained microlitic amygdaloid; much green serpentinized olivine; feldspar extinction angles 12°; 0°; 0°.

Grain

Olivine 6x3; 4x2; 5x4, av. .15x.09 mm.

Feldspar 6x1; 9x1½; 15x1, av. .30x.03 mm.

153.5-165 (Ss. 15851-3). MELAPHYRE, amygdaloidal; at the (11) (1514)

top there is a green decomposed seam; laumontitic amygdules.

Sp. 15851. Hole 16 at 154 feet from bed rock surface. More amygdaloidal than 15850 and more feldspar; much green serpentized olivine; a very little augite also.

Grain

Olivine 9x6; 7x5; 6x5, av. .22x.16 mm.

Feldspar 15x3; 10x2; 10x1, av. .35x.06 mm.

Augite 8x6; 5x1; 7x1½, av. .20x.08 mm.

Sp. 15852. Hole 16 at 159 feet from bed rock surface. Similarly feldspathic; more xenomorphic augite; low angled feldspar, centers decomposed.

Grain

Olivine 8x6; 5x4; 10x8, av. .23x.18 mm.

Feldspar 15x1; 18x3; 11x2, av. .44x.06 mm.

Augite 17x10; 10x6; 10x5, av. .37x.21 mm.

Sp. 15853. Hole 16 at 165 feet from bed rock surface. Microlitic porphyritic; dark red decomposed amygdaloid.

Grain

Olivine 9x8; 6x5; 7x7, av. .22x.20 mm.

Feldspar 21x7; 13x3; 15x2, av. .49x.12 mm.

Augite 18x8; 13x8; 20x12, av. .51x.28 mm.

165-174; (Ss. 15854-5). MELAPHYRE, amygdaloidal. (9) (1523)

Sp. 15854. Hole 16 at 170 feet from bed rock surface. Coarser; very feldspathic; granular augite?

Grain

Olivine 12x12; 10x7; 12x9, av. .34x.28 mm.

Feldspar 16x3; 20x5; 21x3, av. .57x.11 mm.

Augite 21x15; 18x13; 20x13, av. .59x.41 mm.

Sp. 15855. Hole 16 at 174 feet from bed rock surface. A little finer; much decomposed; much olivine.

Grain

Olivine 8x5; 11x10; 7x5; 3x1; 4x3; 7x2, av. .22x.14 mm.

Feldspar 18x2; 13x3; 13x3; 12x2; 20x3; 12x3, av. .48x.08 mm.

174-186; (S. 15856). AMYGDALOID. (11) (1534)

Sp. 15856. Hole 16 at 182 feet from bed rock surface. Coarser feldspar; xenomorphic augite; much low angled feldspar; compact again.

Grain

Olivine 13x9; 20x14; 10x10, av. .43x.33 mm.

Feldspar 15x3; 20x4; 16x3, av. .51x.10 mm.

Augite 13x6; 18x18; 19x10, av. .50x.34 mm.

186-201; (Ss. 15857-8). MELAPHYRE, amygdaloidal; at (14) (1548)

201 feet there is a decomposed green seam, which may be a vein, an inclusion or bomb, or a decomposed margin between two flows.

Sp. 15857. Hole 16 at 186 feet from bed rock surface. Finer grained in contact with prehnitic crack; low angled feldspar.

Grain

Olivine 8x5; 6x5; 6x5, av. .20x.15 mm.
Feldspar 15x3; 15x2; 15x3, av. .45x.08 mm.
Augite 0.

Sp. 15858. Hole 16 at 194 feet from bed rock surface. Very feldspathic; poikilitic augite (?); low angled feldspar.

Grain

Olivine 10x9; 9x7; 8x6, av. .27x.22 mm.
Feldspar 17x3; 13x3; 17x2; 22x3, av. .57x.09 mm.
Augite 20x15; 20x5; 16x13, av. .56x.33 mm.

201-226; (Ss. 15859-62). MELAPHYRE, amygdaloidal. All (24) (1572)

the above series of amygdaloidal melaphyres are small flows of the feldspathic ophite type.

Sp. 15859. Hole 16 at 201 feet from bed rock surface. Vein? or much decomposed margin of two flows; cf. 15843.

Sp. 15860. Hole 16 at 204 feet from bed rock surface. Poikilitic augite; much green olivine; much decomposed feldspar with low or moderate extinction angles.

Grain

Olivine 8x8; 8x7; 10x7, av. .26x.22 mm.
Feldspar 15x3; 16x2½; 13x2, av. .44x.07 mm.
Augite 15x13; 23x16; 15x15, av. .53x.44 mm.

Sp. 15861. Hole 16 at 209 feet from bed rock surface. Prehnitic decomposed; slightly poikilitic.

Grain

Olivine 9x5; 9x6; 9x7, av. .27x.18 mm.
Feldspar 21x5; 18x2; 24x3, av. .63x.10 mm.
Augite 22x20; 24x8; 20x18, av. .66x.46 mm.

Sp. 15862. Hole 16 at 226 feet from bed rock surface. Microlitic porphyritic amygdaloid.

Grain

Olivine?
Feldspar 13x3; 10x2; 10x1, av. .43x.06 mm.

226-258; (Ss. 15863-7). MELAPHYRE, feldspathic (30) (1602)

Sp. 15863. Hole 16 at 231 feet from bed rock surface. Like 15860; low angled feldspar.

Grain

Olivine 9x612x7; 7x7, av. .28x.20
Feldspar 17x3; 27x4; 20x4, av. .64x.11
Augite 18x13; 28x8; 22x20, av. .68x.41

Sp. 15865. Hole 16 at 241 feet from bed rock surface. Fine grained; feldspathic; greenish highly decomposed.

Grain

Feldspar 13x3; 17x2; 20x4, av. .50x.09 mm.

Sp. 15866. Hole 16 at 253 feet from bed rock surface. Quite feldspathic; xenomorphic augite; low angled feldspar.

Grain

Olivine 8x8; 10x9; 9x7, av. .27x.24 mm.

Feldspar 25x2; 16x2; 22x5, av. .63x.09 mm.

Augite 32x13; 24x14; 35x23, av. .91x.50 mm.

Sp. 15867. Hole 16 at 258 feet from bed rock surface. Marked red microlitic porphyritic amygdaloid; very black ground.

Grain

Olivine 10x5; 8x5; 6x5, av. .24x.15 mm.

Feldspar phenocrysts 12x2; 12x2; 15x3, av. .39x.07 mm.

Augite 0.

258-275; (S. 15868). MELAPHYRE. (16) (1618)

Sp. 15868. Hole 16 at 270 feet from bed rock surface. Quite feldspathic; xenomorphic augite.

Grain

Olivine 12x11; 8x8; 9x9, av. .29x.28 mm.

Feldspar 26x4; 19x4; 20x4, av. .65x.12 mm.

Augite 18x17; 26x17; 16x12, av. .60x.46 mm.

275-297; (15869-71). MELAPHYRE, amygdaloidal. (21) (1639)

Sp. 15869. Hole 16 at 275 feet from bed rock surface. Decomposed microlitic.

Grain

Feldspar phenocrysts 19x2; 13x2; 21x3, av. .53x.07 mm.

Augite 0.

Sp. 15870. Hole 16 at 275 feet from bed rock surface. Feldspathic; xenomorphic augite.

Grain

Olivine 6x4; 6x5; 7x5, av. .19x.14 mm.

Feldspar 15x3; 16x4; 20x4; 15x3, av. .55x.11 mm.

Augite 19x19; 12x8; 25x10, av. .56x.37 mm.

Sp. 15871. Hole 16 at 296 feet from bed rock surface. Microlitic porphyritic amygdaloid.

Grain

Olivine 3x3; 5x5; 8x5, av. .16x.13 mm.

Feldspar 20x2; 16x2; 17x3, av. .53x.07 mm.

297-320; (Ss. 15872-3). MELAPHYRE, ophite, amygdaloidal. (22) (1661)

Sp. 15872. Hole 16 at 298 feet from bed rock surface. Microlitic porphyritic amygdaloid; feldspar low angled; much decomposed.

Grain

Olivine 9x6; 4x4; 5x4, av. .18x.14 mm.

Feldspar 13x2; 20x2; 16x2, av. .49x.06 mm.

Sp. 15873. Hole 16 at 307 feet from bed rock surface. Ophitic poikilitic.

Grain

Olivine 7x7; 8x8; 11x10, av. .26x.25 mm.

Feldspar 20x4; 20x3; 11x3, av. .51x.10 mm.

Augite 30x26; 20x18; 43x15, av. .93x.59 mm.

320-348; (Ss. 15874-7). MELAPHYRE; ophite; for the first 13 feet (27) (1688) vesicular and amygdaloidal with laumontite.

Sp. 15874. Hole 16 at 320 feet from bed rock surface. Decomposed feldspathic amygdaloid.

Grain

Feldspar 13x2½; 17x4; 13x3, av. .43x.09 mm.

Sp. 15875. Hole 16 at 333 feet from bed rock surface. Feldspathic; xenomorphic augite.

Grain

Olivine 7x6; 8x7; 8x6, av. .23x.19 mm.

Feldspar 23x3; 19x2; 20x3, av. .62x.08 mm.

Augite 40x22; 23x20; 22x13, av. .85x.55 mm.

Sp. 15876. Hole 16 at 338 feet from bed rock surface. Poikilitic augite. The grain of the augite is given in Fig. 15 on p. 128 of the Isle Royale report (Vol. VI) by points marked c, the rate of increase being normal.

Grain

Olivine 14; 8; 8; 7; 8; 7

Feldspar 22; 3; 26; 4; 14; 4

Augite 35; 25; 40; 25; 32; 32.

Sp. 15877. Hole 16 at 343 feet from bed rock surface. Finer grained than 15876.

Grain

Olivine 6x4; 8x5; 7x6, av. .21x.15 mm.

Feldspar 15x2; 14x3; 17x4, av. .46x.09 mm.

Augite 5x5; 6x3; 11x5, av. .22x.13 mm.

348-391; (Ss. 15878-82). MELAPHYRE, ophite. $\frac{(41)}{}$ $\frac{(1729)}{}$

Sp. 15878. Hole 16 at 348 feet from bed rock surface. Decomposed like 15874.

Grain

Olivine?

Feldspar 15x4; 14x4; 16x3, av. .45x.11 mm.

Augite none.

Sp. 15879. Hole 16 at 351 feet from bed rock surface. Slightly poikilitic augite; labradorite extinction angles 22°-20°w40°-39°; 20°-27°w33°-40°.

Grain

Olivine 10x11; 14x11; 16x5, av. .40x.27 mm.

Feldspar 12x4; 27x3; 18x5, av. .57x.12 mm.

Augite 12x7; 17x10; 17x12, av. .46x.29 mm.

Sp. 15880. Hole 16 at 355 feet from bed rock surface. Very feldspathic but poikilitic still.

Grain

Olivine 13x11; 8x8; 12x6, av. .33x.25 mm.

Feldspar 19x3; 29x3; 18x4, av. .66x.10 mm.

Augite 27x22; 33x22; 25x18, av. .85x.62 mm.

Sp. 15881. Hole 16 at 375 feet from bed rock surface. Coarser; labradorite extinction angles 27°-18°w37°-35°; 21°-23°.

Grain

Olivine 10x8; 10x8; 12x11, av. .32x.27 mm.

Feldspar 12x4; 16x5; 21x3, av. .59x.12 mm.

Augite 130x120; 135x120; 105x80, av. 3.70x3.20 mm.

391-410; (Ss. 15882-4). MELAPHYRE, amygdaloidal. $\frac{(18)}{}$ $\frac{(1747)}{}$

Sp. 15883. Hole 16 at 392 feet from bed rock surface. Feldspathic not very fine grained amygdaloid; microlitic.

Grain

Olivine 5; 4; 5

Feldspar 12x3; 16x4; 10x5, av. .38x.12 mm.

Sp. 15884. Hole 16 at 405 feet from bed rock surface. Somewhat poikilitic; feldspathic; low angled.

Grain

Olivine 9x5; 8x6; 8x4, av. .27x.15 mm.

Feldspar 30x6; 15x4; 15x4, av. .60x.14 mm.

Augite 30x25; 32x20; 18x18, av. .80x.63 mm.

410-438; (Ss. 15885-7). MELAPHYRE, ophite (27) (1774)

Sp. 15885. Hole 16 at 410 feet from bed rock surface. Microlitic; porphyritic; very amygdaloidal decomposed.

Sp. 15886. Hole 16 at 416 feet from bed rock surface. A good deal decomposed; poikilitic.

Grain

Olivine 10x9; 9x9; 8x7, av. .27x.25 mm.

Feldspar 17x4; 28x5; 15x2, av. .60x.11 mm.

Augite 86x80; 70x60; 60x50, av. 2.10x1.90 mm.

Sp. 15887. Hole 16 at 437 feet from bed rock surface. Much finer grained; augite patchy; low angled feldspar.

Grain

Olivine 5x5; 4x4; 7x4, av. .16x.13 mm.

Feldspar 11x3; 8x2; 14x3, av. .33x.08 mm.

Augite 2x3; 1x2; 2x1, av. .05x.06 mm.

438-447; (Ss. 15888-96). BRECCIA OR SCORIACEOUS CONGLOMERATE; 10 1784

BOHEMIAN RANGE GROUP.

a mixture of fine grained sandstone and of a porphyrite like the Huginnin porphyrite.

From this point we shall take off .06 to reduce from VERTICAL *width to* THICKNESS, *implying a dip of about 20°.*

Sp. 15888. Hole 16 at 438 feet from bed rock surface. Contact very fine grained with basic sediment. Distance from margin 438.

Grain

Feldspar phenocrysts 20x3; microlites 4x1; 5x0.5, av. .29x.04 mm.

Sp. 15889. Hole 16 at 439 feet from surface. Large fragment of fine grained porphyrite like Huginnin porphyrite.

Sp. 15890. Hole 16 at 440 feet from surface. Similar pebble.

Sp. 15891. Hole 16 at 441 feet from surface. Similar pebble.

Sp. 15892. Hole 16 at 442 feet from surface. Similar pebble.

Sp. 15893. Hole 16 at 443 feet from surface.

Sp. 15894. Hole 16 at 444 feet from surface. Basic sediment; augite and feldspar.

Sp. 15895. Hole 16 at 445 feet from bed rock surface. Interlocking of sediment with a porphyrite which is very ferruginous but otherwise like the pebbles.

Sp. 15896. Hole 16 at 448 feet from bed rock surface. Sediment and porphyrite with one brotocryst of quartz also plagioclase and microfelsite.

455-475; (Ss. 15897-8). PORPHYRITE; like the Huginnin (19) (19)

porphyrite. No. XIV, 367-436 feet.

Sp. 15897. Hole 16 at 445 feet from bed rock surface. Porphyrite with feldspar brotocrysts like pebbles.

Sp. 15898. Hole 16 at 467 feet from bed rock surface. Slightly coarser with augite granules, and larger magnetite.

475-487; (Ss. 15899-906). CONGLOMERATE, red, with numerous (11) (30) cavities, and much basic debris, but also with a good deal of quartz porphyry which

is sometimes spherulitic; cement largely calcareous. This conglomerate which occurs in No. XII from 471 feet to 493 feet, and in No. XV from 429 feet to 444 feet, being the first bed that can be identified with absolute certainty in all the holes, is said by Stockly to contain *copper* in No. XII. This is natural, as drill hole No. XII seems, as we have said, to lie nearer the fault. This conglomerate would seem to be thickening toward the northeast, and while occurring at practically the same level in both No. XII and No. XVI, is 40 to 50 feet higher in No. XV, as already remarked, thus indicating the fault already mentioned. This is really the first well-marked conglomerate with porphyry pebbles that we have met below the Allouez conglomerate, No. VI, 363-386 feet. It is about (5879-2332) 3547 feet below the latter, and in the remainder of the record we find four considerable conglomerates and at the bottom a porphyry. Now we see in Marvine's table of conglomerates facing p. 60, that after a considerable gap devoid of conglomerates, we have a group, Nos. 8-4, opposite or east of the Isle Royale mine, and Nos. 6-4, opposite or east of the Kearsarge mine, about 6529 feet below the Alloucz conglomerate. Now the ratio 3547:6529 is not far from similar ratios already found for other parts of the series; (see Vol. VI, Pt. I, p. 105). On Keweenaw Point, moreover, porphyries are evidently quite persistent in connection with a lower group of conglomerates, as brought out by Hubbard in the second part of Vol. VI, and as shown also in the recent Indiana drilling, and the porphyries found around Bare Hill and Mt. Houghton, which are much like the Isle Royale occurrence in question. We have no marked change in the character of the lavas at this point as we have above the Greenstone, by which we can make an exact and certain identification, but we may with much certainty say that we have arrived at the top of the lower group of felsitic conglomerates, and as Marvine's No. 8 is the first one which he makes continuous, we will provisionally correlate this Isle Royale bed, or that a few feet above, with it, for thus we best express its position at the top of a group of four closely associated conglomerates. Of course the scoriaceous bed at 438 feet might be taken as Marvine's No. 8, and I have put the bottom of the Central Mine group and top of the Bohemian Range group at that point.

Sp. 15899. Hole 16 at 475 feet from bed rock surface. Microlitic porphyritic with poikilitic quartz porphyry sediment.

Sp. 15900. Hole 16 at 480 feet from bed rock surface. Similar calcareous cement; microlitic fragments changed to poikilitic quartz patches.

Sp. 15901. Hole 16 at 481 feet from bed rock surface. Pebbles of poikilitic quartz porphyry and porphyrite?

Sp. 15902. Hole 16 at 482 feet from bed rock surface. Pebbles of spherulitic porphyry; quartz porphyr; quartz keratophyre; plagioclase feldspar phenocrysts have extinction angles 5°w11°-22°.

Sp. 15903. Hole 16 at 483 feet from bed rock surface. Spherulitic porphyry, porphyrites and fragments of tufa.

Sp. 15905. Hole 16 at 486 feet from bed rock surface. Not very fine grained porphyrite with calcite veins.

487-611; (Ss. 15906-18). Melaphyre, ophite; amygdaloidal (117) at the top; has much more magnetite than, for example, the "backbone" Greenstone. Cf. Pumpelly, Geol. Sur. Mich., I Pt. II, p. 17 and some of the lower beds of the Mass Mine section.

Sp. 15906. Hole 16 at 487 feet from bed rock surface. Calcareous and ochreous, with a brecciated vein; sedimentary or thoroughly decomposed contact with trap.

Sp. 15907. Hole 16 at 490 feet from bed rock surface. Rather fine grained feldspathic porphyrite; calcite cavity; feldspar decomposed; probably low angled.

Grain

Olivine 5x2; 3x2; 3x1½, av. .11x.05 mm.

Iron oxide 3x5; 5x5; 5x4, av. .13x.14 mm.
Feldspar 11x3; 10x2; 18x5, av. .39x.10 mm.
Augite 4x1; 3x2; 4x2.5, av. .11x.05 mm.

Sp. 15908. Hole 16 at 494 feet from bed rock surface. Similar but becoming slightly poikilitic; low angled feldspars (up to 20°).

Grain

Olivine 5x5; 5x5; 5x4, av. .15x.14 mm.
Feldspar 18x3; 15x2; 18x5, av. .51x.10 mm.
Augite 35x22; 24x12; 45x45, av. 1.04x.79 mm.

Sp. 15909. Hole 16 at 524 feet from bed rock surface. Marked poikilitic, but has also a marked nest of coarse feldspar and olivine indicating a troctolite either as an included fragment or early stage of crystallization.

Grain

Olivine 15x15; 17x13; 4x4; 5x3; 3x3, av. .29x.25 mm.
Iron oxide (much) 11x8; 17x14; 60x27; 83x20; 70x17, av. 2.13x.64 mm.
Feldspar 18x2; 20x3; 26x3, av. .46x.36 mm.; av. .64x.08 mm., in the coarse nest.
Augite 60x55; 40x37; 70x47, av. 1.70x1.39 mm.

Sp. 15910. Hole 16 at 531 feet from bed rock surface. Well defined poikilitic but with *much magnetite;* feldspar extinctions, zones 38?°-41°-w19°-15°.

Grain

Olivine 10x6; 6x5; 7x6, av. .23x.17 mm.
Iron oxide 13x10; 13x13; 18x14, av. .44x.37 mm.
Feldspar 25x5; 39x23; 27x5, av. .91x.33 mm.
Augite 72x60; 75x60; 80x55, av. 2.27x1.75 mm.

Sp. 15911. Hole 16 at 539 feet from bed rock surface. Marked poikilitic, very ferruginous; feldspar extinction angles 0°w25°-28°; 30°-16°; 13°w25°-30°.

Grain

Olivine 12x9; 7x6; 12x11, av. .31x.26 mm.
Iron oxide 8x7; 12x11; 11x11, av. .31x.29 mm.
Feldspar 23x3; 36x4; 30x5, av. .89x.12 mm.
Augite 110x80; 53x50; 80x45, av. 2.43x1.75 mm.

Sp. 15912. Hole 16 at 553 feet from bed rock surface. Coarse type with larger feldspar; zonar feldspar extinction angles 19°-12°w28°-23°; 32°-31°w8°-8°; 36°-32°w16°-14° in a large feldspar; both poikilitic and doleritic type of texture with cavities lined with chlorite.

Grain

Olivine 28x20; 30x18, av. .8x.63 mm.
Iron oxide hematite or ilmenite 40x4 and 25x23
Augite 76x60; 70x60; 76x70, av. 2.22x1.90 mm.

Sp. 15913. Hole 16 at 554 feet from bed rock surface. Altered olivine plainer; feldspar extinction angles 6°-11°w28°-23°; 12°-12°w29°-29° in Baveno crystals at right angles.

Grain

Olivine 14x7; 9x9; 9x8; nest 32x4, av. .32x.24 mm.
Iron oxide octahedra 10x9; 6x6, av. .26x.25 mm.
Feldspar 14x3; 18x2; 18x3, av. .50x.08 mm.
Augite 122; 160x75; 80x75; 150x70, av. 3.9x2.2. mm.

Sp. 15914. Hole 16 at 560 feet from bed rock surface. Coarse poikilitic; feldspar extinction angles 6°; 40°-23°; 23°-17°w36°-38°; 19°-24°w37°-45°.

Olivine 8x8; 12x8; 8x8, av. .28x.24 mm.
Iron oxide 12x11; 10x8; 15x12, av. .37x.31 mm.
Feldspar 11x3; 23x2.5; 18x3, av. .52x,08 mm.
Augite with naked eye 3 mm.; 140x80; 110x80; 100x70, av. 3.50x2.30 mm.

Sp. 15915. Hole 16 at 564 feet from bed rock surface. Extinction angles 23°-32°; 23°-20°; 17°w31°-30°; feldspar crystallization far advanced before final vent; nests 35x8.

Grain

Olivine 13x12; 10x8; 11x11, av. .34x.31 mm.

Feldspar 20x5; 13x3; 16x3, av. .49x.11 mm.

Augite with naked eye 3 mm.; 85x60; 105x40; 145x80, av. 3.35x2.05 mm.

Sp. 15916. Hole 16 at 591 feet from bed rock surface. Feldspar extinction angles 15°-26°w32°; 38°-30°w30°.

Grain

Olivine 5x14; 6x7; 9x11, av. .20x.32

Iron oxide 20x12; 10x8; 19x10, av. .49x.30 mm.

Feldspar 15x5; 14x3; 20x5; some big feldspars about 35x9, av. .49x.12 mm.

Augite with naked eye 2 mm.; 85x60; 80x73; 80x60, av. 2.45x1.93 mm.

Sp. 15917. Hole 16 at 607 feet from bed rock surface. Finer grained than 15916 feldspar extinction angles 19°-25°; 17°-26°; 0° and 17°-7°w35°-33°.

Grain

Olivine 5x5; 6x6; 8x3, av. .19x.14 mm.

Feldspar 13x2; 15x2; 10x2, av. .38x.06 mm.

Augite ? 37x32; 31x27; 60x56, av. 1.28x1.15 mm.

Sp. 15918. Hole 16 at 611 feet from bed rock surface. Fine grained amygdaloid?; glomeroporphyritic; large calcite amygdule; feldspar extinction angles 12°-15°; 13°-14°; 3°; 22°-12°; there is one big feldspar and feldspar nests are segregated.

611-618; (Ss. 15919-23). CONGLOMERATE; with basic and acid pebbles; dips observed 21°, 26°, 27°. (7) (124)

Herafter 1-10 will be taken off to reduce from VERTICAL *width to* THICKNESS, *corresponding to dip of 26°.*

Sp. 15919. Hole 16 at 612 feet from bed rock surface. Poikilitic keratophyric porphyrites, etc., calcite cement.

Sp. 15920. Hole 16 at 613 feet from surface. Sediment largely basic with calcite cement but also quartz and porphyry fragments.

Sp. 15921. Hole 16 at 615 feet from bed rock surface. Very calcareous; a few fragments of porphyries.

Sp. 15922. Hole 16 at 616 feet from bed rock surface. Calcite cement; porphyry, quartz porphyry and keratophyre and spherulitic pebbles.

Sp. 15923. Hole 16 at 617 feet from bed rock surface. Various klastic fragments as above.

618-663.5; (Ss. 15924-8). PORPHYRITE. (42) (42)

Sp. 15924. Hole 16 at 618 feet from bed rock surface. Amygdaloidal micrölitic porphyrite with red ground; mostly low angled feldspar.

Grain

Olivine 0

Feldspar 9x1; 9x0.5; 8x1, av. .26x.02 mm.

Augite 0, very black.

Sp. 15925. Hole 16 at 619 feet from bed rock surface. Coarser; olivinitic; low angled feldspar.

Grain

Olivine 2x2; 3x4; 2x2, av. .07x.08 mm.

Feldspar 15x1; 6x2; 15x10, av. .36x.13 mm.

Augite?

Sp. 15926. Hole 16 at 625 feet from bed rock surface. Trifle coarser, shredded augite; extinction angles moderately low; 0°; 16°.

Grain

Olivine?

Iron oxide 1x2; 4x4; 3x4, av. .08x.10 mm.

Feldspar 11x2; 13x1; 10x3½, av. .34x.06 mm.

Augite 6x4; 6x6½; 4x4, av. .16x.09 mm.

Sp. 15927. Hole 16 at 637 feet from bed rock surface. Augite in sharper interstitial granules; moderately low extinction angles 0°, 13°.

Grain

Olivine 3x3; 3x3; 4x4, av. .10x.10 mm.

Iron oxide 3x3

Feldspar 20x2; 31x3; 19x2, av. .70x.07 mm.

Augite 6x4; 9x8; 4x3, av. .19x.15 mm.

Sp. 15928. Hole 16 at 663 feet from bed rock surface. Fine grained chloritic amygdaloid.

Grain

Olivine 2

Iron oxide 2x2; 5x2; 3x0.1, av. .10x.04 mm.

Feldspar 22x2; 6x1; 10x2, av. .38x.05 mm.

663.5-697; (Ss. 15929-38). CONGLOMERATE, scoriaceous; (30) (72)

like 438-445 feet in its character and in its pebbles. It is not at all unlikely that similar conglomerates, which are a brecciated mixture of sandstone and trap, represent real though perhaps slight erosion unconformities, the underlying bed having been eroded. They may also be a sign of terrestrial formation of the series. Dips 28°, 29°.

Sp. 15929. Hole 16 at 667 feet from bed rock surface. Coarse sandstone; grains largely of salic, felsitic rocks; this is very like the bed from 438-445 ft. in character.

Sp. 15930. Hole 16 at 670 feet from bed rock surface. Finer grained but with one large fragment of microlitic porphyritic amygdaloid.

Sp. 15931. Hole 16 at 672 feet from surface. Fine grained microlitic amygdaloid such as occurs near margins of flows.

Sp. 15932. Hole 16 at 674 feet from surface. Shows contact of two flows.

Sp. 15933. Hole 16 at 675 feet from surface. Microlitic amygdaloid, not equally fine grained.

Sp. 15934. Hole 16 at 676 feet from surface. Fine grained basic sediment; basic conglomerate?

Sp. 15935. Hole 677 feet from surface. Fragments of dark ferruginous more or less microlitic porphyrites; cement largely calcareous.

Sp. 15936. Hole 16 at 692 feet from surface. One large similar fragment.

Sp. 15937. Hole 16 at 694 feet from surface. Similar.

697 (or 696)-786; (Ss. 15939-45), MELAPHYRE, ophite; the (80) (80)

bottom five feet are a fine grained brecciated black trap, the dip of the lines of amygdules being 27°.

Sp. 15939. Hole 16 at 697 feet from bed rock surface. Evidently of fragments, but coarser; augite in small patches.

Grain

Olivine 2x1; 3x2; 2x1, av. .07x.04 mm.

Iron oxide 3x2; 5x1; 3x2, av. .11x.05 mm.

Feldspar 10x1; 5x1; 10x1, av. .25x.03 mm.

Augite 15x10; 18x9; 10x7, av. 0.42x0.26 mm.

The grain of this bed is illustrated in Figures 14, 15 (a) and 18 of the Isle Royale report, Vol. VI, Pl. I.

Sp. 15938. Hole 16 at 696 feet from bed rock surface. Similar to 15937; all these sections are similar. Compare the Huginnin porphyrite, in which however the phenocrysts are more distinct.

Grain

Iron oxide 1x2; 2x2; 2x1, av. .06x.04 mm.
Feldspar 10x1; 12x1; 15x9, av. .37x.11 mm.

Sp. 15940. Hole 16 at 700 feet from bed rock surface. Marked poikilitic; much olivine.

Grain

Olivine 5x4; 10x8; 6x5, av. .21x.17 mm.
Feldspar 8x2; 14x4; 12x7, av. .34x.13 mm.
Augite 53x40; 80x80; 115x75, av. 2.48x1.95 mm.

Sp. 15941. Hole 16 at 727 feet from bed rock surface. Marked poikilitic; much olivine; labradorite extinction angles 23°-23°; 21°-18°w33°-28°.

Grain

Olivine 6x5; 8x7; 9x6, av. .23x.18 mm.
Feldspar 13x2; 16x2; 12x2, av. .41x.06 mm.
Augite 105x67; 67x60; 105x85, av. 2.17x2.12 mm.

Sp. 15942. Hole 16 at 739 feet from bed rock surface. Marked poikilitic; much augite; feldspar extinction angles 28°-23°; 21°-18°; 33°-28°.

Grain

Olivine 5x3; 8x7; 7x7, av. .20x.17 mm.
Feldspar 10x2; 11x2; 12x2, av. .32x.06 mm.
Augite 85x85; 100x90; 80x65, av. 2.65x2.40 mm.

Sp. 15943. Hole 16 at 748 feet from bed rock surface. Marked poikilitic; coarser; labradorite extinction angles 24°-19°; 32°-18°w46°-34°; 33°-30°.

Grain

Olivine 8x7; 10x8; 10x7, av. .28x.22 mm.
Feldspar 10x2; 10x1; 12x2, av. .32x.05 mm.
Augite 73x60; 110x65; 52x45, av. 2.35x1.70 mm.

Sp. 15944. Hole 16 at 773 feet from bed rock surface. Marked poikilitic; finer grained feldspar extinction angles 25°-21°w4°-10°; 33°-25°.

Grain

Olivine 4x4; 5x4; 6x4, av. .15x.12 mm.
Feldspar 11x1; 14x1; 11x1, av. .36x.03 mm.
Augite 60x42; 85x65; 52x45, av. 1.97x1.52 mm.

Sp. 15946. Hole 16 at 788 feet from bed rock surface. Calcite and iron oxide. This must be from a vein. Thickness at cross section 732.

786-910; (Ss. 15946-85). SANDSTONE, passing into (112) (192)

CONGLOMERATE and PORPHYRY TUFF. Dips: at 796 feet, 52°?; at 803 feet, 50°; at 808 feet, in a sandstone streak, 63°; at 817 feet, 40°?; at 830 feet, with signs of unconformity and cross-bedding, 35°; at 850 feet, 37°. This bed is very largely of fragments such as the underlying rock might furnish, and largely in the concave forms of ash or glass fragments, which do not imply an erosion of the source, but at the top of the bed there is sediment proper, some of which may have been derived from other rocks than the underlying felsite. At the bottom of this conglomerate the passage into felsite is so gradual that I at first fixed the dividing line at 924 feet, and I think the conglomerate may be considered practically contemporaneous, that is immediately subsequent to the felsite, which was at once subject to erosion, as a land formation quite likely. Chalcedonic dots are characteristic of the whole

formation and a bluish fluorite, first noticed under the microscope, was visible also to the unaided eye. The tufa is sometimes dark, but often light, often greenish, with sandstone boulders, or brecciated with angular green spots.

Sp. 15947. Hole 16 at 789 feet from bed rock surface. Calcite sediment crushed.

Sp. 15948. Hole 16 at 792 feet from bed rock surface. Corroded feldspar! ash fine grain.

Sp. 15949. Hole 16 at 794 feet from surface. Corroded feldspar; spherulitic quartz.

Sp. 15950. Hole 16 at 795 feet from surface. Spherulites; corroded feldspar; long pores with quartz fillings and dark borders.

Sp. 15951. Hole 16 at 803 feet from bed rock surface. Corroded orthoclase feldspar; pores with dark borders.

Sp. 15952. Hole 16 at 805 feet from bed rock surface. Sediment and fragments with fluidal texture.

Sp. 15953. Hole 16 at 807 feet from bed rock surface. Small grains, including plagioclase, green matter, etc., cement micaceous.

Sp. 15954. Hole 16 at 808 feet from bed rock surface. Similar; but with large fragments; some dark; showing flow lines, with spherulites.

Sp. 15955. Hole 16 at 808 feet from surface. Porous brown rock with porous orthoclase.

Sp. 15956. Hole 16 at 812 feet from surface. Plagioclase and spherulites and sediment and rhyolite fragments.

Sp. 15957. Hole 16 at 813 feet from bed rock surface. Microlitic amygdaloid; trichitic pebbles; porphyrite.

Sp. 15958. Hole 16 at 817 feet from bed rock surface. Has curious red and white spots.

Sp. 15959. Hole 16 at 817 feet from surface. Very ferruginous, decomposed.

Sp. 15960. Hole 16 at 822 feet from rock bed surface. Shows perlitic structure outlined by iron oxide.

Sp. 15961. Hole 16 at 823 feet from bed rock surface.

Sp. 15962. Hole 16 at 824 feet from bed rock surface. Porphyry fragments; quartzose or micaceous cement; every fragment outlined by a white line; ash forms.

Sp. 15963. Hole 16 at 827 feet from bed rock surface. The same; more ferruginous.

Sp. 15964. Hole 16 at 829 feet from bed rock surface. Tufa, micaceous; quartzose chloritic?

Sp. 15965. Hole 16 at 830 feet from bed rock surface. Greenish quartzose with reddish spherulite spots.

Sp. 15966. Hole 16 at 836 feet from bed rock surface. Fine grained quartzose mass.

Sp. 15967. Porphyry fragments; quartzose cement; green matter in interstices.

Sp. 15968. Hole 16 at 841 feet from bed rock surface. Similar; green grains in irregular forms representing altered ash?

Sp. 15969. Hole 16 at 842 feet from bed rock surface. White flecks and red flecks are characteristic through this series of rocks.

Sp. 15970. Hole 16 at 842 feet from bed rock surface. Porphyry tuff.

Sp. 15971. Hole 16 at 847 feet from bed rock surface. Porous; pores lined with quartz and filled with chlorite.

Sp. 15972. Hole 16 at 849 feet from bed rock surface. Corroded feldspars; tufaceous; *fluorite* with calcite; isotropic; in blue spots; cleavage good; refraction lower than either refraction of calcite!

Sp. 15973. Hole 16 at 850 feet from bed rock surface. Tufa as usual.

Sp. 15974. Hole 16 at 853 feet from bed rock surface. Perlitic fragments; corroded orthoclase.

Sp. 15975. Hole 16 at 863 feet from bed rock surface. Feldspar; well marked fragments.

Sp. 15976. Hole 16 at 865 feet from bed rock surface. *Fluorite*, glass fragments well-marked.

Sp. 15977. Hole 16 at 867 feet from bed rock surface. Corroded feldspar; rounded, dotted glass fragments.

Sp. 15978. Hole 16 at 870 feet from bed rock surface. More micaceous.

Sp. 15979. Hole 16 at 875 and 878 feet from bed rock surface. Micaceous; fragments of spherulites.

Sp. 15981. Hole 16 at 882 feet from bed rock surface. Calcite in spherulitic form.

Sp. 15982. Hole 16 at 891 feet from bed rock surface. Well marked fragments with white margins as illustrated in I. R. report, Vol. VI. Part 1. Plate VI. Fig. 2.

Sp. 15983. Hole 16 at 896 feet from bed rock surface. Poikilitic ash fragments; chalcedonic dots.

Sp. 15984. Hole 16 at 899 feet from bed rock surface. Similar to 15983.

Sp. 15985. Hole 16 at 903 feet from bed rock surface. Very ferruginous.

Sp. 15986. Hole 16 at 910 feet from bed rock surface. Porous, full of chalcedonic spots, calcite, etc.

910-1000+; (Ss. 15986-98). Felsite, very fine grained; a typical felsite; porphyritic crystals, extremely small and rare; quartz not certainly visible. This, with the Minong felsite porphyrite may seem to meet Irving's anticipation (*loc. cit.*, p. 331) of red acid rocks on the north side of the island. We have already called attention to the felsites that occur at various points in the series on Keweenaw Point. But by far the closest lithological resemblance of this bed is to the felsites of Bare Hill, Sec. 29, T. 58, R. 28, and to those that occur near the mouth of the Little Montreal River on Sec. 26, and Sec. 27, T. 58, R. 28, which are described by Hubbard. It also resembles some of the Mamainse felsites, near Sand Bay.

Sp. 15986. Hole 16 at 910 feet from bed rock surface. Porous full of chalcedonic spots, calcite, etc.; beginning of porphyry here.

Thickness at cross section 822.

Sp. 15987. Hole 16 at 916 feet from bed rock surface. Big corroded feldspar brotocryst; very calcareous and quartzose.

Sp. 15988. Hole 16 at 922 feet from bed rock surface. Open pores; calcareous; quartzose confused porphyry ground mass.

Sp. 15989. Hole 16 at 923 feet from bed rock surface. Calcareous pores; porphyry ground mass with brotocrysts.

Sp. 15990. Hole 16 at 924 feet from bed rock surface. Similar; more compact.

Sp. 15991. Hole 16 at 926 feet from bed rock surface. Similar; less calcareous; I at first thought the beginning of the tufa was here.

Sp. 15992. Hole 16 at 928 feet from bed rock surface. Similar.

Sp. 15994. Hole 16 at 935 feet from bed rock surface. Similar.

Sp. 15995. Hole 16 at 936 feet from bed rock surface. A curious eye is perhaps a brotocryst of feldspar; otherwise similar.

Sp. 15996. Hole 16 at 953 feet from bed rock surface. Distinctly poikilitic with quartz patches.

Sp. 15997. Hole 16 at 964 feet from bed rock surface. Similar.

Sp. 15998. Hole 16 at 1000 feet from bed rock surface. Small corroded quartz brotocryst.

For records of hole XII and XV see Isle Royale Report, Vol. VI. Part I. pp. 95-97.

§ 35. MAMAINSE.

One further section with which I am familiar may have a word of mention. At the east end of Lake Superior north of the Sault Ste. Marie Keweenawan rocks are found. Here we find the thickest section perhaps at Cape Mamainse.[1] Here we find 2000 or 3000 feet of not very thick flows of ophitic type and conglomerates subordinate with a heavy 20 mm. ophite at the bottom. Under this is a set of beds with five important conglomerates and felsitic beds near the top. Next comes a very heavy conglomerate 680 feet thick, and then several thousand feet of not very thick flows with occasional diabase dikes, numerous amygdaloids, and no important conglomerates. Felsites occur from very near the top down and are often intrusive. In one place the upturned lower beds are overlain with an entire unconformity of strike and dip by sandstone that we may identify with the Lake Superior sandstone.

It seems as though the Central and Bohemian Range groups were represented.

This report has so extended that I will not try to give details of the section for which see Bull. 6 cited above. The important features for comparison are that we have here conditions very similar to those on Keweenaw Point or Isle Royale. The dips vary from about 24° to N. 35° W. at the top of the series to 42° or more toward the base. The formation is a good deal disturbed by faults which are, however, not so predominantly vertical as on Keweenaw Point. The main set strike nearly north, to east of north, and dip 45° to 65° E., thus making southward pitching troughs with which the occurrence of copper is associated. Not only are the beds as already mentioned similar to those of Keweenaw Point but they are markedly similar in the occurrence of copper. Native copper occurs in some of the conglomerates. It is more abundant in some cases, at any rate, near the cross-fissures as it was, for instance, at the Central mine on Keweenaw Point. It seems, however, to be rather more often a sulphide. In the cross-fissures both chalcocite and chalcopyrite occur. In one place one of these fissures had at the center nearly four solid chalcocites but masses of native copper also occur in the fissures.

Finally, in connection with the probably intrusive felsites disseminated pyrite occurs. We have practically the same secondary fillings of agates, prehnite, etc., that we have on Keweenaw Point. The occurrence of copper in so similar surroundings at the other end of Lake Superior suggests how intimately its occurrence is bound up with the Keweenaw formation itself.

[1]See various reports of the Canadian Survey, and Ontario Bureau of Mines; also Bulletin 6, Department of Mines, Ottawa, Canada.

CHAPTER VI.

TEMPERATURE OF THE COPPER MINES.

§ 1. IMPORTANCE OF THE SUBJECT.

In Fernekes' and Stokes' experiments on the deposition of copper leading to the formation of native copper very analogous to that found in the mines, the solution was unequally heated, copper being deposited in the lower or hotter end. It will be quite fitting, therefore, to discuss what effect the fact that the mines are hotter at the bottom has had on the deposition of copper and for that reason alone to gather facts as to the temperatures prevailing in the copper mines, but these temperatures have also a bearing on the solubility of various substances, and on the probable circulation of water. From a practical point of view, also, they are of importance as they might limit depth in mining. Too great heat decreases the efficiency of men, though it increases that of compressed air machines. It might, therefore, involve an extra expense in ventilation, which might turn a proposition from a profitable to an unprofitable one. However, at what seems to be the actual rate of increase, 1° F for each 100 feet or more, beginning at a temperature of 43° F, it is probable that the increased cost of hoisting and keeping up the roof will be more vital factors.[1]

§ 2. MEAN ANNUAL TEMPERATURE OF AIR.

The average mean temperatures of the Upper Peninsula, according to the map (Fig. 1) furnished by the State Weather Bureau for U. S. Geol. Sur., Water Supply Paper 31, would be 38° to 42° F. Calumet is about 1200 A. T. (See Pl. IX.) The record of temperature at Calumet is not quite so long as that at Marquette. The former runs only from July, 1887 to March, 1910 and the average for the various months and for the year are, as given by the State Weather Survey, C. F. Schneider, director, as follows:

[1] See "Mineral Industry," 1895, p. 767, "How Deep can we Mine?" A. C. Lane.

MEAN TEMPERATURE AT CALUMET.

January	15.6° F
February	13.8
March	22.3
April	37.0
May	46.3
June	59.4
July	64.3
August	62.2
September	55.4
October	43.7
November	30.4
December	21.1
Year	39.4

If we assume that during December, January, February and March, owing to the snowy covering, the temperature of the ground is practically 32°, (as it is where covered on the level with snow, though of course, there are spots which are exposed and frozen much deeper where the wind has blown away the snow) and if we suppose also that during the month of April, when the mean annual temperature is 37°, the soil temperature is still kept down by the blanketing of snow to 32°, we shall have an increase of 4.10° to add to the mean annual temperature (39.4°) to get the mean soil temperature,—that is 43.7°. This is near enough in agreement with other observations and with the temperatures of the upper mine levels considering the rough method of approach. The temperature (43.3° F at 80 feet) of the flow of water from the Calumet and Hecla drill hole No. 10, would indicate a somewhat lower mean soil temperature, but it must be remembered that the covering of snow is quite irregular, and the correction due to it, which as we have seen is a very appreciable one, must be equally irregular. The thirty-three year mean for Marquette (which is only 600-700 A. T.) is 40.5 F.[1] The difference may be attributed to elevation and exposure. Jackson gives the mean temperature of Copper Falls as 42.11° F, but I do not know the length of time of the observations. It is true, however, that mean temperatures for one year as high as that are reported very frequently at Marquette. Foster and Whitney (p. 41) give the following mean annual temperatures:

[1] U. S. Dept. Agr. Weather Bureau (Bulletin S) No. 408, April 1909.

Fort Brady from 36.6 to 41.6, average 39.82
Fort Wilkins 41.46
Mackinac 41.67

Numerous other data may be obtained from C. F. Schneider of Grand Rapids, chief of the State Weather service.

§ 3. MEAN ANNUAL TEMPERATURE OF UPPER MINE LEVELS.

If we wish to get the mean annual temperature of upper mine levels we may make direct observations which are liable to be affected by the ventilation of the mines. We are able to make better inferences from diamond drill holes, in case water flows from them,—as occasionally does happen. The temperatures of springs are also of importance.

Of especial interest are the observations made by C. T. Jackson in his old report[1] since they were taken before mines were deep and there was a chance for heating effect by warm air rising from below. We may make the following tabulation from his report.

JACKSON'S OBSERVATIONS, 1844.

Page	Mine	Depth	Temperature F	Remarks
412	Lac la Belle	100	44.6	Springs in drift
412	Lac la Belle	100	50	Drift July 10, air outside 77°
413	Lac la Belle	140	44°	
443	Lac la Belle	179	48	Air
			45	Water July 15, air outside 71°
		Upper	47	Air
			44	Water
447	Copper Falls	130	48	Air, air outside 64°
462	Copper Falls	120	44½	Air
		20	44½	Air
458	N. American	155	44	
		123	45	External air 59° Sept. 23
		95	43	Spring
459	Boston & Pittsburg	236	45	Rise of 1° in 88 ft.
		180	43	
		120	44	
		60	44	

It may be worth noting that (p. 498) temperatures for Lake Superior ran from 9° to 2.5° C mainly about the maximum density of water which is 3.5° C or 38.3° F.

It is clear that the temperature at the "invariable depth" (that is to say a depth at which the temperature did not vary appreciably during the year) was 43°F to 44°. Jackson assumes 43° as the

[1]Annual Message and accompanying documents, 1849-1850, Pt. III

mean surface soil temperature. This is entirely confirmed by later observations. Prof. H. A. Wheeler gives a temperature of 43.3° at 112 feet. Smillie found 44.5 in the breast of a drift at the top of the Quincy mine 332 feet above Lake Superior, i. e., 200 feet ± below the surface. Wells and springs have temperatures from 43° to 45°—rarely below. See the data collected by F. Leverett in a recent Water Supply paper (160, pp. 30-44) of the U. S. Geological Survey.

§ 4. RATE OF INCREASE.

An article by H. A. Wheeler[1] gives observations on mine temperatures as follows:

	Gradient	—Depth— Upper	Lower	—Temperature— Upper	Lower
Atlantic	99.5	111	907	43.6	51.6
Central	101.	90	1950	42.6	61.
Conglomerate (Delaware) or (Manitou)	95.	90	617	42.8	48.3
Quincy	122.	111	1931	43.	58.5
Osceola	76.5	136	996	42.3	54.5
Tamarack	110.7	136	2200	43.	62.

In the 1901 report, page 245, I gave some tests at the Champion Copper mine, in 1902 at the Champion Iron mine and Freda, and I have other notes all tabulated below:

Depths in parentheses are vertical from surface; otherwise they are along the lode or hole, and may or may not be.

[1]Am. Jour. Sci. (1886) XXXII, Art. 13, pp. 125-138. Also St. Louis Acad. Sci.

Mine	Depth	T. F.	Date	Remarks
C & H Hole d 10	80	43.3°	Aug. 25, 1908	Elevation 436 feet above Lake. Strong flow, alkaline, flowed when 80 feet deep. The hole is deeper. (See section, Fig. 36).
Lake Copper Hole d 5	110 to 186?	45°		Perhaps from first amygdaloid at 207 feet; cased to bed rock at 123 feet, 408 feet above Lake Superior. (See Fig. 51).
Freda well drilled by churn drill	100 480 550 636 770 730 700 to 950	45.5° 51.?° 51.5° 51.5° 50.° 49.° 55° to 55°.6	during drilling	Sheldon. The drill house was warm and it was hard to set the thermometer and get it into the bailer without danger of its making observations uncertain.
Porcupine Mts., Union Spring Old launder near Boston	0	43° 48°	Aug. 1908	
Spring		47	Aug. and Oct. 1908	Half way from Ontonagon to Porcupine Mts.
Champion Copper	(130) (250) (378)	44.5 45. 46. 47. 52.1	July 24 1901 1901 1901 1909 Aug. 4	1st level 2nd level Damp rubbish Air in 3rd level 13th level (water?)
Trimountain Victoria mine Nonesuch mine Isle Royale	1350 (270) (620)	46. 57. 42. 53. 57.	1906 1908 Sept. 1908	3rd level 18th level Near surface Section 12 shaft
Champion Iron	(465) (1335) (1500) (1650)	45.8 52. 55. 56.5	1902	9 L 250 feet west of 7 shaft 24 L 140 feet west End of 26 L End of 28 L 750 feet from 5 Shaft
Aragon Vulcan Iron	80-90 (1090)	44. 56.		Water Water
Republic Iron	1153 1435	55. 59.		Water
Central Copper	(2400)	61.	Dec. 6, 7, 8, 1894	J. F. Roberts foot of No. 2 shaft, 30th level
Centennial	3100 (1850)	69. 62.		Osceola lode on slope Level at foot of shaft Calumet conglomerate

Mine	Depth	T. F.	Date	Remarks
Ojibway 33 °dip	(680) 1225	50. .		
Wolverine	(520) (860)	48. 51.		8th level cross-cut 13th level cross-cut
Franklin Jr.	400 level (200) ± (1600)	45-46 61.	Oct. 13, 1906	Temperatures of waters (See Fig. 40) 21st level cross-cut from conglomerate to the Pewabic lode newly opened
Old Franklin	3200	62-63		On 32nd level, according to G. Pope
Tamarack N	(4400)	84.	July 13, 1909	R. M. Edwards
18th level	(5223)	85.		
bottom	(5367)	88 to 91.4	Observations in A. C. Lane	damp mud
Tamarack 5	(4662)	82.		W. E. Parnall
Tamarack 5	(4900)	87.		J. Hall, mine inspector

We have also an interesting set of observations of temperature in the Quincy mine from S. Smillie, Engineer.

Temp. Fahr.	Elev. above Lake Superior	Remarks
		Surface runs from 480 ft. to 550 ft. A. L. S. at mine, but drops rapidly to south
44.5	+332	Breast of drift
50	-390	Breast of long cross-cut
55	-580	In diamond drill hole after 5 min.
57	*-580*	In diamond drill hole after *3* days
52.5	-580	Near top of cross-cut
52	-580	Near bottom of cross-cut
67.5	-2441	Breast of drift
64.5	-2441	In diamond drill hole 5 days
68.5	-2590	In breast of drift
74	-3120	Shaft in good circulation
75	-3120	In airway between 2 shafts
69	-2696	In breast of drift
71	-2903	In breast of drift
74	-3316	In cross-cut
79	-3316	In breast of drift
80	-3316	In another drift
76	*-3375*	In diamond drill hole cross-cut after *40 hours*.

The observations in italics should be extra reliable.

The rate of increase of temperature according to T. C. Chamberlin, who has had the Calumet and Hecla observations from A. Agassiz to write up, is 1° in 103 feet for 4939 feet, assuming that at 50 feet the invariable temperature is 40°, or 1° F in 93.4 between 3324 feet and 4837 feet.[1] But as we have seen, the surface invariable temperature should be taken some 3° higher which would lower the rate of increase to 1° in 105 feet. Smillie's high-

[1] Geology, Vol. I, p. 569.

est (80°) and lowest (44.5°) results at breast of drift give the same gradient (35.5°/3650) as Chamberlin's uncorrected figure; his drill hole observations (29/2795) 1° in 104. There is, however, an uncertainty amounting to several hundred feet as to what should be taken as the mean depth of the lower stations, for not only the elevation of the surface directly above but also that of the surface all around for two or three miles should be considered and the Quincy mine stands at the brink of the Portage Lake trough.

Obviously, too, if any part of the surface is a relatively recent thing like a mine dump, it will have no effect on the temperature thousands of feet below. Indeed we may well ask (as we do below) if all the superficial and glacial deposits have not been deposited since the bottom of the mines acquired their temperature. While the general level of the country, from which the depth should be measured to warmer parts of the mine, is the same for the Calumet and Tamarack mines, yet the Tamarack shafts are 40 feet or so above the Calumet shafts so that really equivalent depths will appear that much deeper in the Tamarack. On the whole, plotting all the tests and weighing them, 1° in 105 feet seems to me the most probable average rate of increase but it might possibly be as low as 45° in 5000 feet, 1° F in 111 feet. This in any case is lower than in many places in Michigan.[1] In the Lower Peninsula, rates of increase of heat nearly twice as great are known (at Grayling and Alma) and rates of increase four times as great and more are found in other regions.

§ 5. EXPLANATION.

For explanation of this relatively low rate of increase at present we can not (as did Wheeler) appeal to the cooling effect of Lake Superior. The phenomenon is too wide spread. Moreover, the difference of elevation between the height of the range and the depth of Lake Superior (1105+834) is only 2000 feet and less, which in a distance of 20 or 30 miles (See Fig. 3) could make but trifling differences in the flow of heat,[2] for we must remember the difference of mean temperature is certainly less than 5° F. The temperature at the bottom of Lake Superior is that of the maximum density of water 39° F. A depth beneath Lake Superior as hot or hotter than the surface of Calumet would be only 2500 feet lower at a distance of many miles. The Freda well, near Lake

[1]But not so low as that given in a "preliminary" note by A. Agassiz, which unfortunately, owing to its extreme character, has been widely cited and copied. Am. Jour. Sci. (1895) p. 503.

[2]See B. O. Peirce on the trifling effect the temperature of the sides of a cylinder whose radius is five times its height has on the temperatures along its axis. Proc. Am. Ac. Arts and Sciences, Vol. XXXVIII, No. 23, May, 1903, pp. 651-660.

Superior, shows no extra chill, and the Champion Iron mine far from Lake Superior shows an extra low gradient. Even if we suppose that the chilling effect of Lake Superior were so great as to make the temperature at the bottom of the mines the same as if the temperature at Calumet were that of Lake Superior, which of course is extreme, it would change the gradient only 10%. Thus Wheeler's, and more recently, Königsberger's suggestions[1] as to a topographic effect of Lake Superior upon the gradient appear to be wide of the mark. I doubt if the Lake Superior effect is appreciable.

More important in reducing the temperature may be some of the following causes.

(1) Endothermal reactions, that is reactions that (like the solution of salt in ice) lower the temperature.

(2) High diffusivity of the strata, permitting the early and free escape of heat.

(3) Downward absorption of waters, carrying with them cooler temperatures of the surface.

(4) Recent change of surface climate which presumably has grown milder since the ice age.

(5) The recent deposition of surface drift.

(6) Relative exhaustion of the internal supply of heat by the Keweenawan and earlier eruptions.

Let us briefly consider these in their order. (1) In the experiment by Fernekes in which copper was formed in an unequally heated tube, it was found at the heated end. Then according to the principles of entropy and the second thermodynamic law, formation of copper must have been a chemical reaction that tended to absorb and use up heat and bring the temperature of the solution into equilibrium rather than accentuate the differences. It is a reducing action and tends to absorb heat just as oxidation gives out heat. This reason for low gradient is especially worth emphasizing if one is contrasting the gradients in western sulphide deposits that are partially leached, where oxidation and consequent rise in temperature may have taken place. I do not mean to say that the reduction of the copper in itself used up enough heat to produce the low gradient, but that it tends that way. Other reactions were of the same character. Brun has found silico-chlorides in volcanic glass. Reactions which start with calcium and chlorine in solid condition and wind up with it dissolved are strongly endothermic and changes which resulted in

[1]See Report of International Geological Congress at Mexico, 1906, pp. 1127-1137, also Central Blatt f. Mineralogie Geol u. Palaeontologie, 1907, pp. 200-203.

calcium chloride in solution instead of ferrous or cuprous chloride would be in so far forth endothermic, and so would change from calcium chloride to sodium chloride which, in discussing the alteration of boulders in the Calumet and Hecla conglomerate[1], I have shown probably takes place.

Two of the commonest minerals associated with the copper in the Keweenawan rocks are epidote (Sp. Gr. 3.3 to 3.5) and prehnite (Sp. Gr. 2.8 to 2.95). They are denser and occupy less volume than average trap. The chlorite into which the Calumet and Hecla boulder[2] changes is probably denser than it. The decomposition of basaltic glass to epidote or epidote, calcite and chlorite would pretty surely not be an expansion.[3] According to the principles emphasized by Van Hise[4] then, these changes implying condensation of volume also imply absorption of heat.

It is true that light zeolites like analcite, natrolite, laumontite and others of that family are also produced. But they are *very largely in the upper levels*, and in the open cavities and veins. If we imagine relatively cool, though actually hot, waters working into a series of hot lavas and reacting upon them, the reactions forming these secondary minerals are such as would be thermally natural, being such as would tend to reduce the thermal differences.

(2) The conductivity of samples of trap, amygdaloid and conglomerate have been determined by B. O. Peirce[5] as follows:

		Conductivity k	Est. diffusivity $a^2 = k/c$.
Trap	11	0.0031	.0056 to
"Hanging?"	22	0.0036	.0045
Amygdaloid	1	0.0035	.0065 to
"Foot?"		0.0034	.0044
Calumet conglomerate	111	0.0047	.0061
	2	0.0052	.0066

The diffusivity must be obtained from the conductivity by dividing it by the specific heat capacity for unit volumes $a^2 = k/c$. Unfortunately c was not determined, but the specific heat capacity for a number of minerals is as follows: (1) according to Chemisches Taschenbuch (2) according to White.[6]

[1]Economic Geology, 1909, p. 158, (IV, No. 2, March).
[2]The decomposition which I described in Economic Geology, 1909.
[3]This decomposition is discussed in Chapter II, p. 87.
[4]Monograph XLVII, U. S. G. S., p. 185.
[5]Proc. Am. Soc. Arts and Sci., XXXVII, No. 23, May, 1903, pp. 651-60.
[6]See figures by W. P. White, of the Geophysical laboratory at Washington, Am. Jour. Sci. Vol. 28, (Oct. 1909) p. 342.

	(1)	(2)
Olivine	.189	
Orthoclase	.191	.257 to .279
Wollastonite		.251 to .261
Albite	.196	
Diopside		.262 to .278
Corundum	.197	
Hematite	.167	
Quartz	.191	.184 to .264
Calcite	.205	
Copper	.093	

If we multiply the specific heat capacity for unit weight by the specific gravity we shall get the specific heat capacity for unit volume. The specific weight of these rocks must be between 2.65 and 3, according to McNair's tests,—the conglomerate probably about 2.76, the others about 2.84 to 2.88. The resulting *c* will be about .51 to .77 for the conglomerate, and up to .8 for the amygdaloid and melaphyre. Peirce found for various marbles specific heats per unit volume from 0.567 to 0.586 and diffusivities from 0.009 to 0.013, the conductivities 0.005 to 0.0076. The conductivities are much like those observed on the Carlton Hill trap of Edinburgh, and they are more than those of some slates; less than those of many rocks and marbles, and can not be far from characteristic for the formation. They should imply a low, but not remarkably low, gradient and I do not think that the gradient can thus be wholly accounted for.

(3) We have elsewhere discussed the indications that the copper was deposited by downward working waters. Such a method of deposition is consistent with the chemical arrangement of the waters and with the absorption of the waters either by hydration or as a result of the cooling off of the formation. Such a circulation of water would also help to cool it off.

One point may be noted, however, for future research. If the cooling is produced by downward circulating waters, then the more pervious beds should be a little the cooler and the less pervious massive traps relatively warmer, so that the copper might tend to form between them, working toward the warmer part of the solution and the walls of the lode. This, indeed, it seems to do. The temperature difference would hardly be measurable with a thermometer now, but may have been marked when the copper formed.

We see, then, that we may have had thermometric conditions not unlike those of Fernekes' and Stokes' sealed glass tubes. So that it is perfectly possible to conceive copper deposition going on

without any other circulation than convection currents and ionic migration similar to that in those tubes. Of course, such reaction would be very slow, but its relatively coarse crystallization is exactly what gives Lake Copper its peculiar toughness as compared, for instance, with electrolytic copper. According to J. B. Cooper copper deposited in a week electrolytically is fine and short and can not be rolled. If four weeks are taken it is tougher and rollable, and a year might give a quality like that of Lake. Dr. L. L. Hubbard has a single crystal of copper 2½ inches across and branching forms showing equally coarsely crystallized copper are not uncommon. The calcite crystals which are so closely associated with the copper are often many inches through and indicate very slow formation.

Lincio has described some quartz from Hancock[1] presumably from the Quincy mine, with calcite and native copper which showed new quartz faces.

Now it will be noticed that these quartz crystals showed trapezohedral faces, and Mügge has shown[2] (and the matter has been farther investigated by Wright and Larsen[3]) that while quartz in general only forms below 800°, such quartz only crystallizes below 570° C. Hence the copper which replaces quartz and comes later must also have formed at temperatures as low, and as its coarseness shows, in a fluid in which there were but slight differences of condition.

(4) Another possible cause of low gradient would be a colder climate in the past. In the not very remote past (perhaps less than 10,000 years ago) the Great Lakes covered practically all of Keweenaw Point. At a somewhat earlier date it was covered by melting ice. These two events might imply a surface soil temperature of 39° respectively 32°. A gradually increasing mean soil temperature amounting to 11° and beginning 14,500 years ago could cause a variation of less than half a degree (0.44° F) at a depth of 5000 feet. A gradient of 1° in 111 feet would be produced from one of 1° in 89 feet in 5000 feet. A change of 11° in surface temperature would change the gradient at the Champion Iron mine from 1° in 111 feet to the normal gradient of 1° in 67 feet. If the effect of the increase of annual temperature and milder climate had not penetrated the full depth the lower parts of the mine would tend to have the original gradient and that may account for the more rapid gradient (1° F in 93.4 feet) which

[1]Neues Jahrbuch fur Min., B. B., XVIII, p. 155.

[2]"Ueber die Zustandsanderung des Quarzes bei 570°," by O. Mügge. Neues Jahrbuch fur Min., Geol. and Pal., 1907, pp. 181-96.

[3]Quartz as a Geological Thermometer, Am. Jour. Sci., Vol. 27, (1909), p. 421.

according to Chamberlin is found in the Calumet mine between 3324 and 4837 feet. It may even be possible to work backward, and from the gradient at different depths estimate the date since the surface temperature ceased to be 32° F. But before doing this we should need to take into account also the next factor to be considered.

(5) There is a sheet of deposit of glacial or later origin. If the bottom of the mines are too deep to be affected by the post-glacial rise in annual temperature, they are also too deep to have been affected by any blanketing effect of this addition. Thus their temperature assumed to have been fixed by a gradient adjusted to a 32° F surface temperature, was also adjusted not to the present surface but the base of the glacial deposits. Not only this, but there are indications in kettle holes, etc., that considerable masses of ice were buried in these deposits, which slowly melting may have kept them at 32° F for some time after the departure of the ice sheet proper. Subtraction of the glacial deposits would, however, make less than a foot per degree difference in the Calumet district in the rate of increase. It might make more difference in the interval to be assumed between glacial time and the present milder surface temperature.[1]

But if any effect of the ice age is in turn cause of the low gradient in the copper mines we ought also to find low gradients in the Lower Peninsula of Michigan, which was also at a geologically recent date covered with ice. In the Lower Peninsula the increase of temperature through the drift is very rapid and the gradient thence down is not unusually low.[2] This renders it very doubtful if any part of the low gradient of Keweenaw Point should be attributed to a climate that has recently grown warmer.

(6) It must also be true that in the immense outbursts of lava that accompanied the Keweenawan, and also occurred in earlier formations, there was a considerable exhaustion of the sources of heat from beneath and a lowering of a relatively cool basement, upon which this series of lavas was piled, down deeper into the earth's crust than it would otherwise have been. If, for instance, we consider (Fig. 57) a section of crust of three layers, (a), (b) and (c), and we consider the effect of the eruption as a geologically in-

[1]If the milder surface temperature is supposed at once to have had its full effect and amount at the end of melting of the last enclosed ice block, then the increase of temperature at a depth x at a time t thereafter will be roughly $C\,(1-P_{x/2a\sqrt{t}})$.
C is the increase of temperature say 11° and P is the probability integral, the values of which for different values of the subscript argument are given in the report for 1903, page 222. And if, when $t=o$ $u=a+Cx$, and thereafter $u=C$ if $x=o$, then $u=a+cx+C(1-P_{xy})$ where $y=1/2a\sqrt{t}$
See Byerly on Fourier's Series.

[2]Report for 1901, p. 244 et seq. The Bay City and Grayling observations are most reliable except for water circulation.

stantaneous transfer of (b) to be piled up on (a)[1], the increase of heat from the surface to A will for a long time be much less than before.[2]

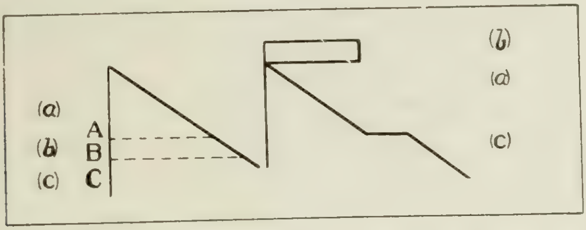

Fig. 57. Diagram to illustrate distribution of temperature in the earth's crust after the outflow of Keweenawan lavas.

The section (a) can be given some initial temperature between 1800° F and 200° to 400° F which lower temperatures the zeolites indicate were widely prevalent. Of course, there is little or no likelihood that it was anything like 1800° for 40,000 feet, but it is worth noting that since after a million years there would be nearly half the original temperature left in the middle of the formation, but after 25,000,000 years the temperature in the middle dependent on the initial temperature would be but .0116 of the original temperature (supposing always that the formation is 40,000 feet thick), after 25,000,000 years there would even of this maximum temperature only be 4.5° left. The middle section (a) would have initially a gradient beginning with the surface temperature or zero at the bottom of the lava formation. At the point from which the lava was drawn between B and C there would have been a sudden jump up to a gradient as high as ever, reckoning from the top of the eruption rather than the bottom. (Fig. 57.) Such distribution is, of course, not exactly one that ever was really in existence but is sufficiently of the type to show the kind of effect that might be expected. Pages might be filled with computations of the various temperatures that might be obtained at different depths after different times and under different conditions. Suffice it to say, that if we assume a diffusivity of 203 in feet and years instead of 400 as used by Kelvin (since the former agrees better with the conductivity found by B. O. Pierce) we shall obtain the following results.

If we consider that the depth of the Keweenaw formation was 40,000 feet and the next layer 140,000, so that the third layer began at 180,000 feet and that the rate of increase of temperature was

[1]Which it was not. No doubt a lot of heat escaped in the process.
[2]See Byerly "Fourier's Series" pp. 83-84.

one degree in 70 feet, then after the 25,000,000 years aforesaid the temperature at a depth of 5000 feet would be 53.8° F above that at the surface, plus a certain amount dependent upon the initial temperature of the Keweenaw formation which could not exceed 5.2° F. Thus instead of a gradient of one degree in 70 feet we should have a gradient of one degree in 85 to 93 feet, and if this were compared with a surface temperature which had recently been raised 11° above 32° it would give gradients as low as those we have. After 49,000,000 years an original gradient of 1° in 70 feet would still be 1° in 96 feet possibly increased by initial temperature to 82°. An original gradient of 1° in 60 feet would become 1° in 83 or 79 feet. It thus appears that while a recent change to a milder climate may have had something to do with the low gradient, which is promoted, too, by a rather high diffusivity of the rocks, this would also be promoted by something which had an equivalent effect, to wit, the tremendous loss of heat along with the outbursts of lava that took place at an early date and that these various factors are sufficient, if we make no unreasonable suppositions (in fact the most natural suppositions we can from independent data in regard to the thickness of the formation and the lapse of time since) to account entirely for the low gradient. And yet it seems to me that a downward migration of waters that incidentally produced cooling reactions, such as the solution of calcium chloride in water or ice, may also have been of importance.

Thus while I am not inclined to agree with the reasons for low gradient given by previous authors, we are not devoid of other explanations,—in fact we have an embarrassment of riches—and while as regards the effect of endothermic reactions we can not claim for them the importance which I frankly confess I had hoped (in beginning this research) I might have found, we can still say that the low gradient is not inconsistent with endothermic reactions and with downward working waters. It will probably be a long time before we have such an accurate idea of geologic time, of the thickness of the formation, and of other factors involved that we shall be able to say at all definitely which part of the low gradient must have been due to each factor.

§ 6. MATHEMATICAL SOLUTION.

For solution of the problem we can consider an infinite solid cooling through one plane to the surface of the earth which is kept at zero, the mean annual temperature of the earth at the time being taken as zero. And taking the time when the lava was poured out

as a beginning of time at that time ($t = 0$) the temperature was a function of the distance from the margin. Suppose, for instance, that it were 1800° down to a depth of $x = b$ (say 40,000 feet) for the Keweenaw formation. This is a much higher temperature than is probable but we will keep the term separate in our solution so that we can readily see by simple replacement what the effect of any other initial temperature would be. From the point $x = b$ on, suppose the temperature rises at a certain rate—say 1° in 70 feet. This ratio, too, we will keep by itself and treat as an algebraic expression so that any other ratio may easily replace it. Suppose this ratio to continue down to a 180,000 foot depth $= c$. From this the lava came with an initial temperature (assumed 1800° F[1]). Then the solution of the temperature after a given time is given by Byerly (Fouriers Series, page 84, equation 7, etc.), and may be written in the following form. It will be convenient to write.

$y = 1/2a\sqrt{t}$ and $\frac{2}{\sqrt{\pi}}\int_0^m e^{-m^2}\,dm = P_m$ the probability integral

Then the temperature u is

$$u = \tfrac{1}{2}\,1800^\circ\,(2\,P_{xy} + P_{(b-x)y} - P_{(b+x)y})$$
$$+ \frac{1}{70}\left(x + \frac{b}{2}P_{(c+x)y} - \frac{b}{2}P_{(c-x)y} + \frac{(b-x)}{2}P_{(b-x)y} - \frac{(b+x)}{2}P_{(b+x)y}\right)$$
$$+ \frac{1}{70}\cdot\frac{e^{-(b-x)^2y^2} - e^{-(b+x)^2y^2}}{2y\sqrt{\pi}}$$

Tables of values of P are found in Johnson's Theory of Errors, the the report for 1903, etc., and of powers of e in Byerly and the Smithsonian mathematical tables just issued (Hyperbolic functions, 1909).

§ 7. PROPAGATION OF HOT AND COLD WAVES INTO SNOW.[2] BY H. L. CURTIS AND A. D. PETERS.

A solution of the partial differential equation

$k\frac{d^2v}{dx^2} = \frac{dv}{dt}$ for the propagation of heat waves shows that $k = v^2\pi\ T/4\ \pi$ where k is the diffusity, v the velocity of propagation and π the period; provided the heat wave is simple harmonic.

In the following we have in all cases assumed that the wave is simple harmonic. We have determined in two cases the Fourier Series representing the curves, but find in all cases that our data are too incomplete to make this desirable.

Two sets of data were taken, one from 9 p. m. January 27, 1905 to 9 p. m. January 29, the readings being taken every three hours. To secure satisfactory results we found that the readings should be taken oftener. The snow which was on the ground thawed.

[1]This may not be the temperature which the rate of increase assumed would give for the depth C, for probably much of the heat would be dissipated in the eruption.

[2]I have to thank the Michigan Agricultural College for these data showing the low diffusivity and blanketing effect of snow. Letters, Aug. 4 and Oct. 21, 1905. L.

and a new fall of snow permitted us to get a second set of readings on February 14, 1905 from 7 a. m. to 6 p. m. In the first set of data the time temperature curves show well defined maxima and minima though the curves are far from simple harmonic. The velocity of propagation of two waves could be easily determined, one being a warm wave and the other a cold. In the case of the warm wave the period was taken as the time between the maximum temperature on either side of it, and the period of the cold wave was similarly determined. The velocity was determined from the time temperature curves.

In the second set of data the readings did not extend over sufficient time to obtain more than one maximum. The period could not be determined, so was taken arbitrarily as 24 hours. Otherwise the computation is as above. The following table will be self-explanatory:

Time of maximum at surface.	Kind of wave.	Period.	Velocity in cm. per hour.	Diffusivity in cm. ^{2}/hr.	Diffusivity in cm. ^{2}/sec.	Conductivity in c. g. s. c. units.	% of volume of snow that is H^2O.	Depth of snow. in c. m.
12 M. Jan. 29.	warm	15 hr.	3.3	13.3	0.0037	0.00041	22.1	29
6 P. M. Jan. 28.	cold	23 hr.	1.9	6.6	0.0018	0.00020	22.1	29
2 P. M. Feb. 14	warm	24 hr?	3.83	28.0	0.0078?.	0.00055	14.2	17
Smithsonian						.00051		

The conductivity was determined as follows. The specific heat of the air contained in the snow is neglected. The specific heat of ice is given in the Smithsonian Physical Tables as 0.5. The specific heat per unit volume is therefore 0.5 times the per cent of water in the snow.

As per your suggestion I have computed from our data the values of the diffusivity from the decrease in amplitude of the temperature wave. From the curves a table of the depths and amplitudes of each wave was made. The amplitudes were taken as the distance from a cold maximum to a warm maximum and the period as twice the time intervening. A curve was then platted for each wave, of the depths as ordinates and logarithms of the amplitudes as abscissas. The points of this curve should then lie on a straight line and a line can be drawn giving a mean value. Then the difference between the logarithms of the amplitudes at any two depths can be determined from the curve and a value of the dif-

fusivity computed from this will be a mean value for the wave. The diffusivity was computed from the formula $\log a - \log a_1 = x \sqrt{\frac{\pi}{Tk}} \log e$ where a and a_1 are the amplitudes, x the difference in depth, T the period and k the diffusivity. The following table gives the result:

DIFFUSIVITY FROM DIMINUTION IN AMPLITUDE.

Cold max. at surface.	Warm max. at surface.	Mean period.	Diffusivity in cm ^{2}/hr.	Diffusivity in cm ^{2}/hr.	Conductivity in c. g. s. C units.
6 A. M. Jan. 28, '05	12 M. Jan. 28	12 hr.	11.1	0.0031	0.00034
6 P. M. Jan. 28.	12 M. Jan. 28	16 hr.	20.0	0.0056	0.00062
6 P. M. Jan. 28.	12 M. Jan. 29	35 hr.	17.8	0.0050	0.00055
Mean values of above			16.3	0.0048	0.00050?
Mean former values			16.0	0.0044	0.00039
Final mean			16.2	0.0046	0.00044

CHAPTER VII.

MINE WATERS.

§ 1. HISTORICAL INTRODUCTION.

In our study of the chemical alteration and of specific gravity we have mentioned incidentally the fact that the mine waters had a peculiar character. While the fact that the deeper waters around Lake Superior were peculiarly salty has been known for over twenty years it was not known at the time of Pumpelly's study because the mines had not reached the depth where this feature became characteristic. The first published analysis of Lake Superior mine waters, showing their salty character at depth, that I know is that of the Silver Islet mine, within sight of Isle Royale but on the Canadian side of the boundary. This analysis should, perhaps, be included geologically with the iron country waters (since the mine is in Huronian rocks) but the salt content is very heavy and the water may derive its salt content from Keweenawan intrusives.

I am told by W. W. Stockly who at one time worked with Mr. L. G. Emerson, one of the most prominent early engineers and an assistant of R. Pumpelly during the time Pumpelly was preparing Volume I of the Geological Survey, that Mr. Emerson took samples of some salt water which was struck at about sea level at the Cliff mine. Johnson Vivian says that this water was 1800 feet down. The plan of the mine in the Mineral Statistics report (for 1880) shows the bottom of the mine at the 220— fathom level, 1680 feet below the top of the Greenstone. It was probably struck, therefore, about 1879, but I have found no printed references to it. The Silver Islet water, analyzed by W. M. Courtis, is described in the Canadian reports.[1] The analysis is also given in my papers before the Lake Superior Mining Institute.[2] The next analysis published and the first which called my attention to the matter was made by Prof. R. L. Packard when I was at the Michigan College of Mines.

It was not, however, until many years later that I fully realized the wide spread characters and the geological importance of these waters. It is obvious that if we find included in the copper country rocks three different kinds of water distributed in fairly hori-

[1]Canadian Geological Reports, H. 1887, pp. 28, 58.
[2]Vol. XIII, p. 74.

zontal layers we can be reasonably sure that there has been no round and round circulation since these waters have been thus arranged. The question as to how thorough the circulation of water in the upper levels of the earth's crust has been is one which has been much discussed of late years, particularly by Van Hise and Kemp, and papers on this subject are listed and reviewed in Kemp's annual review of the literature of ore deposits in the annual volumes of Mineral Industry. I have given some preliminary results of my own work in a series of papers.[1] It was natural for me to do this because I had in mind the continuation of my study of the water resources of Lower Michigan by a study of the waters of the Upper Peninsula which naturally led me to take up the study of mine waters. I shall not repeat in full the data which I have heretofore given except where necessary to aid in the solution of the problem, but I shall summarize them, give new data which I have accumulated having a bearing on the problem and correct misprints. The more I looked into the matter the more I found it of geological and practical importance.

§ 2. SUMMARY OF RESULTS.

The study of these waters is of practical interest, in the first place, because the admixture with the upper waters of the lower, strongly saline waters affects the use of the mine waters in boilers. The study may lead to a different plan of pumping and other handling of the mine water. In the second place it seems fairly clear that the character of the waters has had a good deal to do with the deposition of the copper. It is a curious and significant thing that we seem to find traces of similar waters high in chlorides in other districts in which native copper occurs and it is interesting to notice that heretofore[2] in the discussion of ore deposits the importance of chlorides seems to have been little regarded compared with sulphates, in general.

Finally, the chemical character of these waters seems to also bring up very interesting questions as to possible changes in the chemical character of the ocean throughout geologic time and also the question whether the Keweenawan rocks were laid down in

---

[1]Annual report to the Board of Geological Survey for 1903, see p. 141. Report of the State Geologist: "Salt Water in the Lake Mines," Portage Lake Mining Gazette, Mar. 8, 1906; Lake Superior Mining Institute, Vol. XII, p. 154-163; "Chemical Evolution of the Ocean," Journal of Geology, XXVI, April-May, 1906, p. 221; brief description of the Geology of Keweenaw Point, Lake Superior Mining Institute, Vol. XII, pp. 81-104; Mines and Minerals, Dec. 1906; "Salt Water in the Lake Mines," Lake Superior Mining Institute, March 18, 1907; "The Early Surroundings of Life," Science, August 2, 1907, p.129; "Chemical Evolution of the Ocean," Bull. Geol. Soc. Am., Vol. 17; letter on Mine waters, Calumet News, Apr. 10, 1908; Native Copper Times, Apr. 21, 1908; Portage Lake Mining Gazette, Apr. 19, 1908; Mine Waters; Abstract for Proc. Lake Superior Mining Institute, June 1908; Michigan Miner, July, 1908, p. 13; Mine Waters, Lake Superior Mining Institute, Vol. XIII, pp. 63-152; Mine waters and their field assay, Bull. Geol. Soc. Amer. Vol. 19, pp. 501-512.

[2]A paper has recently been published by C. R. Keyes, Economic Geology II, p. 774.

the ocean or whether these waters may not have been derived from saline pools in the deserts. It may also be said that the study of these waters has its bearing upon all the theories of chemical alteration and change of these rocks and also upon the question of the temperature and the rate of increase of temperature which will be found going down. The facts and conclusions summarized below are those which are particularly important if true. I begin with those most firmly established and pass to others of which I am not so sure.

(1) In the copper country as in the iron country the surface waters are soft as compared with those of the Mississippi Valley and generally are more like those of New England. This is true also of the actively circulating waters.

(2) In the copper country, in the iron country and in the sandstone country of the eastern part of the Upper Peninsula, below the layer of soft waters, in which there is relatively active circulation, there is a layer of water in which there is a marked amount of sodium chloride. The chlorine rises steadily, the sodium rises and the calcium rises too, so that we may say that calcium chloride is present. Moreover, as we get to deeper waters calcium chloride predominates. This second or middle layer of water, however, contains sodium in greater quantity than we can imagine to have been produced by simple mixture of the surface waters in which there is a small amount of sodium carbonate and silicate with the deeper waters in which the calcium chloride dominates very largely over the sodium chloride. In other words there is a distinct belt of sodium chloride waters.

(3) Beneath the second belt will be found water extremely strong and practically saturated in many cases with calcium chloride. The ratio of calcium to chlorine becomes nearly 1 to 2. Such waters are extremely corrosive in boilers and pumps and, of course, hard.

(4) In this presence of calcium chloride they resemble waters which are found in connection with similar associations of copper, trap and red sandstone in Chili, in New Jersey and in the Sahe-Nahe region on the west bank of the Rhine. We also find similar waters in the older rocks all over the Mississippi Valley and in fact more or less all over the world. Such waters seem at least in part to have been buried with the strata now containing them and may be called connate waters.

(5) Flows of these deeper or connate waters when struck in mining decrease and soon drain off showing that there is no open connection with the surface.

(6) The exact level at which a given strength of water is found varies greatly, but below 1500 feet it is common to find them stronger than the present sea water (Sp. Gr. 1.028).

(7) The proportions of the different salts are very different from those in present sea water so that we must suppose that they are not derived from ocean water or that the ocean itself has changed in composition (which there is good reason to believe) or that these waters have also changed in composition since they were enclosed.

(8) I can explain the strength of the strongest of these waters only as that of the residue left after most of the water had been absorbed in hydration of the rock.

(9) The third or lowest kind of water not infrequently contains a measurable amount of copper chlorides.

(10) Similar chloride solutions may be made artificially to precipitate copper very much as it occurs in the mines upon prehnite and other minerals which tend to keep a solution alkaline, if such a solution containing copper is kept unequally heated.

(11) The mode of occurrence of the copper, the chemical character of the alterations of the rock, the character of the copper shoots, and the low temperature gradient are all consistent with the theory that the migration or circulation of water in the Keweenaw rocks is not mainly a mere up and down or a round and round circulation but an absorption or imbibition of water by the strata acting like a sponge in which process of absorption of the water the copper is formed and accumulated in a zone of relatively low oxidation in which as it replaces chlorite and prehnite and other minerals which tend to keep the solution alkaline or at least not acid, it tends also to accumulate with other positive ions at the alkaline or negative (cathode) or warmer end of the solution.

(12) This production of native copper may be associated with the production of ferric iron built into epidote from ferrous iron.

(13) The accumulation of copper is also associated with reactions by which the calcium of the calcium chloride is replaced by sodium derived from the rocks, sodium silicate being very largely removed in the process of decomposition, which accounts for the sodium of the middle zone of water.

(14) When the accumulation of alkalis becomes sufficiently high, alkaline zeolites, etc., may be formed, but this is toward the end of the deposition of copper and in the upper levels, where it may be redissolved and migrate downward.

(15) The ultimate source of the copper would seem to be the

formation itself, effusive as well as intrusive beds in the same, together with copper possibly originally dissolved in the water. But there is some indication that the sulphur came from intrusives or fissures.

(16) The general average of copper from extensive sludge analyses would seem to indicate that the whole rock formation ran something like .02% of copper and analyses of the stronger mine waters would indicate that copper in the strong chloride waters may run as high as eight to sixteen milligrams per liter.

In accord with the idea above developed that the copper forms where a chloride solution of the same is kept alkaline by sodium silicate in other alkali dissolved from the rock, we are not surprised to find the copper running into the hanging and foot wall of the porous bed proper, and so (if we may use the data of experiment and physical chemistry as a guide) we may expect to find the copper near pervious streaks, but in the part that was hotter,[1] that which was more alkaline and reducing,[2] that which was electrically positive[3] (cathode).

§ 3. METHODS AND PRECAUTIONS.

Since in testing mine waters contamination by urine, etc., and nitroglycerine fumes might be expected, an analysis of urine was included in the Lake Superior Mining Institute paper. Both urine and nitroglycerine fumes contain other substances by which they may be easily identified, such as phosphates and nitrates.

While larger samples were taken where possible and convenient, a great many tests of the stronger waters like a series from the Calumet and Hecla and Challenge properties were taken in quantities from 30 cc. down, which proved ample, if the sample was accurately measured, when there were many parts per thousand of solids.

There were also made a great many preliminary tests of concentration with urinometer and refractometer. The latter enables one to get an idea of the concentration even to a drop.

DR. G. FERNEKES' ANALYSES.

In talking over the matter with Dr. G. Fernekes, of the chemical department of the College of Mines, he expressed a very keen interest and willingness to take the matter up more systematically. His experiments in reproducing copper were his own free contribution

[1]Near the less porous rock at bottom and sides in case of down circulation, at the center of the lode in case of up circulation.
[2]Associated with green colors, chlorite, epidote, prehnite, rather than red laumontite, etc.
[3]Perhaps, therefore, also on the north side.

to the advancement of science, and he also made a series of tests of mine waters, which went far beyond what he was paid for.

In all cases chlorine, calcium and total solids were determined. In many cases computing sodium enough to satisfy the acid, made solids enough by summation very nearly to agree with those obtained by "heating to incipient fusion," which latter is the way the total solids were determined for the lower stronger waters. This gave results a "little too low" as "some of the calcium chloride was broken up." This method was not employed for the upper waters that might contain large proportions of carbonates. In a number of cases other substances were determined, the bromine most commonly. When the bromine is not determined it is probably included in the chlorine. In a few cases exhaustive tests were made, and tests for copper and nickel more widely. Iron and alumina were measurable in the Quincy waters.

The results are given in grams per liter, oz. per cubic foot. The specific gravity was determined for about a dozen of the waters. As is shown by Figure 58 it pretty closely follows the rule that

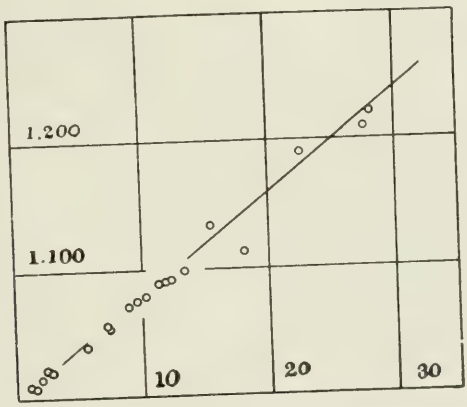

Fig. 58. Diagram illustrating connection experimentally determined between specific gravity and concentration of mine waters, the ordinates being the specific weight, the abscissas, the per cent of solids.

ten-eighths of the excess of specific gravity is the percentage of total solids.

It is quite clear that no serious adulteration with urine or nitroglycerine could be introduced without introducing quantities of nitrogen in some shape—it might be oxidized to nitrates—that should be recognizable. It is also clear that the tendency of such adulteration will be to increase the relative proportions of sodium. No such adulteration can change our general results.

§ 4. IRON COUNTRY MINE WATERS.

The first definite indication of calcium chloride waters in the iron mines came to my attention in testing to see whence a flood of water in the lower levels of the Vulcan mine might have come. From the analysis of this water, page 155 of the annual report for 1903, taken in connection with the surface water analyses (p. 156) I inferred an admixture of a small quantity of calcium chloride water, and that there was no *direct* connection with the surface, or the alkalis would be higher. I suspected this flood to be connected with caverns in the Randville dolomite, and it is said (priv. com. W. Kelly) to come from the talcose underlying schists.

The temperature of the water at the 12th level, 1,000 feet from the surface, was: at the shaft, 57. 2 F.; at the first winze, about 100 feet west of the shaft, 60.°6; and the west end, almost 300 feet west of the shafts, 58.2 . (See annual report for 1901, p. 246). According to the observations there, the mine water at 1,210 feet was 56°, and at 270 feet, 45.°8. This water is then, abnormally warm—either from working up (?) or the heat from casing, friction and decayed timber.

The question arose whether it had any immediate surface source, and accordingly, analyses were made of the surface waters, which will be found in the annual report for 1903, p. 156. In them the chlorine is from 3.8 per million down, the alkalis high.

In a later flood[1] the output increased from 600 gallons per minute to 2,000, the increase being from a flow of water in the pump station on the 15th level. About Dec. 10, a sample was taken and analyzed, column (1). On March 19, 1904, it reached a maximum of 2,807 gallons and has since fallen off fairly steadily, being not much affected by the seasons. By March 26, 1907, the flow had fallen to about 1,000 gallons per minute when it was analyzed again by G. Fernekes with the results given in column 2. The decrease was principally in the flow in the 15th level pump station which "comes from the talcose slates underlying the north ore formation."[2] In the mean time at the west end of the 15th level a flow was struck "coming from the slates overlying the north ore formation," 1,300 feet west, about Sept. 1, 1906, amounting to about 250 gallons a minute, and this was tested, analysis 3.[3] Comparing these Vulcan analyses 1, 2 and 3, it is clear that the hardness remains fairly constant, and there is always practically all the bicarbonate it can hold if there is no excess of CO_2,[4] but with

---

[1]Priv. Com. Agent W. Kelly, Mar. 10, 1907, and earlier.
[2]U. S. G. S. Monograph 46 by Bayley, pp. 221-2, 452.
[3]Analysed by G. Fernekes, May 10, 1907.
[4]Volume VIII, Pt. 3, p. 212, saturation is 95 parts per million Ca, 105 fixed, 210 total CO_2.

time and the addition of the new sources at the west end the chloride dropped, the alkalis rose and approached the amount in the surface waters. Judging from the analyses of the talcose schists given by Bayley (loc. cit.) the alkalis are not leached from them or the Randville dolomite, and the first water struck which had no alkali *seemed* to come from that direction. The abundance of potassium relative to sodium in column 2, may be connected with the fact (loc. cit. p. 379-389) that potash was found in 11 of 15 samples of ore analyzed, soda in but five and generally seems less abundant in the ore. The later analyses and the exhaustion of the flood which has come to pass show quite clearly that no mistake was made in inferring from the analysis that it was not directly from the surface and would run down.

Analysis (1) has the characteristic of the early connate waters, chlorine high relative to sodium.

VULCAN MINE WATERS.[1]

	1	2	3
Insoluble matter, clay & SiO_2	4.4		
Solid solubles	340.00	344.00	303.63
Organic matter	52.3		
Carbon dioxide	37.3CO_3	163.00	171.00
Non volatile solids	250.4		
In solution.			
SiO_2	5.8	9.8	11.2
Al_2O_3	4.4	18.2	1.7
Fe_2O_3	trace		
Ca	60.3	62.29	62.3
Mg.	37.7	28.20	30.5
SO_4	43.0	13.14	11.2
Cl	61.	18.68	
K	trace?	13.	3.7
Na K	p. n. d tr.	6.	11.03
Sr. Li.	0		
Total by addition	209.2	332.31	
Diff., organic, and undetermined Li, Ba, etc.		11.96	

In the same way the Ishpeming mine water (loc. cit. p. 157), given below, shows a greater amount of chlorides than is at all normal to the superficial waters of the Upper Peninsula, though not so

[1]Analyses in parts per million. Analyst, for 1 E. E. Ware for 3 and 2, G. Fernekes.—Location given above.

much that it might not be attributed to organic contamination, which however, the geological conditions render unlikely.

An Ishpeming mine water, collected by A. Formis, coming out of a diamond drill hole at a depth of 825 feet, gave the following results in parts per million.

1		2.
Lime as carbonate		55.8
Oxide determined		31.3
Magnesium as carbonate		17.0
Oxide determined		8.1
Iron and alumina carbonate		.5
Oxide determined		.7
Requiring CO_2	33.2	
CO_2 actually determined		34.3
Total encrusting solids		73.3
Chlorides as sodium chloride		56.2
Chlorine determined		34
Sulphates as sodium sulphate (25 Na)		67.0
SO_3 determined		33.4
Total corrosive solids		123.2
Silica		10.5
Water of crystallization[1]		3.2
Excess of CO_2		1.1
Combined CO_2		33.2
Sodium chloride		56.2
Organic matter by difference from ignition loss		19.9
Ignition loss		113.6
Total by computation		229.1
Total by evaporation at 105° C.		232.2
Difference (minor errors, extra weight of potash over soda and undetermined)		3.1

Analysis by Kirschbraum, computation by A. C. L.

I took, myself, with Mr. E. A. Separk, the chemist, a sample of water from the Aurora mine, Gogebic range, 200 feet west from A shaft about 900 feet down, on the 5th level at a point which had been opened five months. The temperature of the water as taken

[1]The sulphates are probably in large part calcium sulphate, etc., and the soda correspondingly carbonate, reducing the amount of crystallization water.

was 67° F.; of the drift at a dryer place 57° F. The water was coming down on top of the 60-foot kaolinized dike which crosses the formation there.

The analysis is as follows:

December 8, 1904.

Sample marked—Oliver Mining Co., Aurora mine water, Ironwood, Michigan.

	Grams per liter.
Total solids	.1420
Loss on ignition	.0544
Silica	.0122
Iron and aluminum oxides	.0012
Lime	.0354
Magnesia	.0150
Sulphuric anhydride	.0044
Chlorine	.0160
Sodium oxide	.0037
Carbon dioxide	.0510
Organic matter	.0034

F. K. Ovitz, Analyst.

Upon evaporating fifty cc. of the water to which a few drops of hydrochloric acid had been added to three or four cc. the spectroscope showed no test for potassium. No phosphorous was found. The organic matter is taken as difference between loss on ignition and carbon dioxide.

Here again while the total solids are not greater than might be found in any surface water, and the chlorine not greater than might have been artificially introduced, the amount of chlorine is more than twice what can be combined with the alkalis (Na : Cl :: 23 ; 35.5 :: .0037 : .0057) and the presence of calcium chloride and the admixture of a small quantity of water containing this in solution must be inferred.

Sometimes the amount of residual chlorine is so great as to affect the use of the mine waters in boilers. This instigated tests of the Hurley (Superior and Ottawa) mine waters which will be found in the L. S. M. I. paper.[1] These mines are just over the line in Wisconsin, and not very deep—5th to 12th levels.

Through H. H. Smyth I was enabled to get a very much stronger water from the Germania mine of the Harmony Iron Company at Hurley, Wisconsin, an analysis of which will be found in the Cana-

[1]Proc. Lake Superior Mining Institute, Vol. XIII, p. 71.

dian Mining Institute paper.[1] In it Ca (.205) : Cl (.638) = .345 and there was sulphate. It was found in a huge vug, a solution cavity which is 700 or 800 feet east of the shaft on the 14th level, close to it on the 11th and 12th and pitches therefore flat to the east, like the dikes, but seems to follow a big crack or fissure that comes in and dips to the south against the foot wall which dips north. The vug was full of the salt water (1.585 per thousand at 110°, after ignition at low heat 1.005) and of a gas that put out the candles, hence was probably CO_2. I visited this great cavern with water corroded sides in June 1909. The water from the bottom of the shaft gave Ca 1.426 and Cl 3.793. Ca : Cl = 0.376.

These salt waters occur all along the range to Sunday Lake. Through Mr. George H. Abeel, Jr., I was enabled to get tests of the deepest mine, the Newport mine (north half of Section 24, T. 47 N., R. 47 W., just east of Ironwood), which is looking, I am told, as well as ever at the bottom. At 1750 feet a dike came in carrying lots of ore, and it will be noted that the water is relatively fresh. This dike may possibly be a split of the one in the Aurora mine. Mr. Abeel's tests of chlorine show that the water is less saline just on the dike than below or from a diamond drill hole in the hanging, and much less saline than at the Yale which is not so rich. His results are:

Number.	Grams per liter Cl.	Position in Newport mine.
22	.105	On 15th level about 1180 feet from surface.
21	.14	16th level, under dike.
14	.14	17th level, under dike.
25	.07	On 17th level, on dike.
24	.14	On 17th level, 20 feet in foot.
23	.07	Diamond drill hole in hanging.
27	tr.	Above dike, about 1300 feet from surface.

The Newport is under a hill. The next, the Yale, is in a transverse valley farther east on the range, in the S. ½ N. W. ¼ Section 16, T. 47 N., R. 46 W. Here again down (863 feet vertical) to a flat dike cutting the formation at the 10th level no trouble was found in using the mine water as boiler water. Then the trouble began. A sample of water pumped from the mine when at the 15th level (1200 ft. vertical) gave E. B. Smith 13.12 grains per gallon Cl.
0.227 " " "
as against, from the adjacent Colby, ———
12.8 grains

[1] Vol. XII, pp. 124 and 126.

I took two samples, (1) representing the whole mine, which yielded 125 gallons of water a day, about 50 gallons coming above the 10th level and practically fresh, the balance (75 gallons) below that level gave in grams per liter

		(1)
		0.710 Cl
	to	0.568
		0.781
	Hardness =	0.260 Ca
(2) representing that below the 10th level		1.070 Cl
	to	1.170
		0.429 Ca
	Hardness =	0.540 Ca

It is apparent from these tests compared with the tests of George H. Abeel, Jr., that the bulk of the water below the 10th level is that coming above the dike at the 20th level or like it. We may also infer that the water above the 10th level will run about 0.18 grams per liter which is more than that above the 5th level, and less than the average water in the cross-cut. Arranged in order of concentration Abeel's field tests gave.

Number.	Chlorine.	Position in Yale mine.
9	.07	Above 5th level.
2	.35	10th level cross-cut, raise above 3rd dike.
5	.14	10th level cross-cut above 2nd dike.
1	.14	10th level cross-cut below 2nd dike.
17	.28	10th level cross-cut above 1st dike.
8	.14	12th level on dike.
10	.14	14th level above dike.
20	.42	17th level diamond drill hole in hanging.
18	.49	17th level above dike.
19	.84	19th level above dike.
16	.84	19th level below dike.
15	1.33	20th level on dike.
11	.84	21st level below dike.

To explain the references to dikes we remark that the iron bearing formation of the Gogebic range is cut across by Keweenawan dikes, and that the iron ore lies in troughs made by them and by an impervious foot wall. Most of the water of the mines comes in along these dikes which are kaolinized as described in a previous chapter. So it was of interest to see if any connection between the chlorine and these dikes could be obtained. A long cross-cut cut into the hang-

ing at the 10th level gave a chance to test that. There is but slight difference. The iron ore bodies seem to have a little fresher water, and so on the dike it is sometimes a little fresher, but on the whole the circulation was so long ago that the inequalities in concentration seem to have nearly spread out horizontally. Indeed, it is not sure that the slight effect observed may not be due to circulation started in mining. It must also be remembered that there are faults nearly parallel to the strike, which act like another foot wall to make with the dike a trough for the accumulation of iron ore. These faults, (though strike faults) can be recognized by the way they displace the dikes. As these dikes are of Keweenawan age it is conceivable that they introduced the chloride waters after the iron ore bodies formed, for pebbles of the latter are found in the Keweenawan conglomerates. Salt water is also reported farther west around Sunday Lake in the Brotherton mine and near Wakefield, but has not been farther studied.

REPUBLIC MINE T. 46 R. 29.

Captain Peter W. Pascoe reported a salt water coming at a vertical depth of 1153 feet from the surface in the 16th level, 600 feet northwest of the No. 9 shaft. With Messrs. Siebenthal, Slaughter and Pascoe I visited several places in the deeper part of the mine where saline waters came in, testing with total reflectometer and urinometer, and taking a sample of the strongest.

At 1153 feet down, 600 feet northwest of the No. 9 shaft a drip from a drill hole and fissure which has a temperature of 55° to 56° F. and precipitated iron freely on the floor of the drift, seemed fresh and showed an index of refraction near that of fresh water. This was from an east-west seam. A seam with quartz and coarse hematite ran N. N. E. and dipped 45° to S. E. The ore body dips 80° and pitches 45°.

On the 1435-foot level, say 700 feet from No. 9 shaft, was another flow, temperature 59° and there was a more appreciable amount of salt. On the 1710 level near the Pascoe or south end of the mine the strongest water was almost drained off[1] from a fissure making an angle of 32° with the drift, dipping 24° or so north of west. The temperature was 57° to 57.5°, the Sp. Gr. by urinometer 1.025 to 1.027. The analysis by Dr. G. Fernekes is as follows:

[1]It is characteristic of the *strong* calcium chloride waters that they appear in limited quantity. More than once I have been told of one by a mining captain, and upon going to the place found not enough to test. Somewhere lower we might find it.

	Grams per liter.
Ca	7.902
Na	7.290
Mg	.566
Cl	25.360
SO_4	1.045
CO_2	not determined
Al_2O_3	.700
Mn	tr
Fe	tr
Sum	42.863
Total solids	45.590

CHAMPION IRON MINE T 48 N., R. 30 W.

A sample was sent in by the agent, W. H. Johnston, which came from the 28th level, 800 feet east of No. 5 shaft and was taken with great care by Harry R. Hulst. It was a *slow* drip.

It gave the following results:

Sp. Gr. 1.0037. This would correspond to about .5% $CaCl_2$ and .51 NaCl.

	Grams per liter.
Total solids by evaporation, including combined and crystal water	7.100
Chlorine Cl	3.050
Calcium Ca	0.810
Sulphate ion SO_4	0.370
Alumina Al_2O_3	present
Carbonates CO_2	very low
Iron	0

M. A. Cobb, Analyst.

The ratio of Ca : Cl = .27 is not very far from that of the Republic sample just cited (.313).

Salt water is also said to have come out of a drill hole in the foot wall south from the 17th level No. 4 shaft and no doubt traces of calcium chloride water could have been found higher up if tested for.

This mine shows well the contrast between the upper circulating waters and these lower ones. Very little water is said to come in below the 800 to 900-foot level. The salt water is said to come mainly on the 28th and 30th levels. A pump at the 1000-foot level takes care of practically all the water. When I visited it, July 2,

1909, they had done no pumping below that level since August 21 of the previous year, at which time it was bailed out in one day in about 50 skips. This mine is an unusually interesting one owing to the metamorphic change. Grünerite, chloritoid (masonite) and tourmaline are found. The latter occurs down in the 20-23rd level and some more was recently found about 2000 feet from No. 7 shaft in the 3300-foot level. I mention these facts as they might have some bearing on the composition of the water.

§ 5. COPPER COUNTRY WATERS.

The first published analysis of Lake Superior mine waters of which I know is that of Silver Islet, within sight of Isle Royale but on the Canadian side of the boundary which should perhaps be geologically included with the iron country waters as it occurs in Huronian rocks, but it is very strong and may be associated with a Keweenawan intrusive.

The water in the Silver Islet mine[1] was noted also for the presence of combustible gas, which came in vugs penetrated by drills with salt water below 500 feet.

The calcium chloride water, I am informed by W. M. Courtis, who was employed as chemist there, came in a bore hole on the north side of the shaft at 560 feet from the surface.

We calculate from the original figures given in the L. S. M. I. report.

Cl[2]	22.53
Na	6.45
Ca	6.23
K	.25
Mg	.34
SO_4	.047
CO_3	.177

Na : Cl 0.275

PEWABIC LODE.

The next analysis published and the first I personally heard of was the one made by Prof. R. L. Packard, of water reported by an error as from the Huron mine, in Wadsworth's annual report for 1892, p. 174.

---

[1]See Canada Geological Reports, H. 1887, p. 28, 58.
W. McDermott, Eng. & M. J., Feb. 3, '77, p. 53.
T. Macfarlane, Trans. A. I. M. E., VIII, 1880, p. 226; XVII, p. 296, and earlier volumes, i. e., IV, V, IX, XV, p. 671.
Data of Geochemistry, U. S. Geol. Survey, Bull. 330, p. 144.
[2]In all the mine waters there appears to be bromine which is presumably included in the chlorine when not given separately.

I was assured by Capt. J. Vivian that the sample was really from the Franklin.

The full figures, both of the analysis of the general mine water and of the boiler water are given there and in the L. S. M. I. paper.

Attention was first called to it and the analysis made because of the trouble it made in the boilers. This was when the mine was down to the 25th or 26th level (1610′ on the lode) about 1300′ below the surface.

Another analysis of the general mine water made in Chicago at about the same time is given also.

Cl	4.739 per thousand
Na	1.583
Ca	1.378
K	.086
Mg	.030
Fe, Al, Si p.n.d. compare following analysis.	
Organic	
CO_3	.088
SO_4	.174
	8.078
Undetermined	0.437
Total solids	8.515
Na:Cl	.33
Ca:Cl	.29

The second analysis was as follows:

Cl	2.694 per thousand
Na	.763
Ca	.784
Mg	.056
K	.077
Fe	.012
Al	.016
Si	.134
CO_3	.046
SO_4	.213
Organic	.027
Sum	4.827
Na : Cl	.283

It comes from the same general lode and horizon as the Quincy mine waters analyzed by Koenig, Fernekes and Steiger below, and the water from seams in the Franklin Junior cross-cut and their work on the Pewabic lode is also from geologically a similar horizon and depth. The relatively greater amount of sodium as compared with them is marked. But these are analyses of a composite water.

QUINCY MINE.

The Quincy mine was of especial interest as offering the deepest mining on the amygdaloid, and as being the one in which copper in the mine water first attracted attention. It was not easy to obtain satisfactory samples in the upper old workings.

I am informed by Prof. J. Fisher that in the Quincy mine flows good to drink were found on the 13th level, and on the 26th level, but that on the other hand a drill hole in the hanging between Shaft 1 and 2 just N. E. of the old man engine shaft on the 26th level was too salt to drink. This is about 2,000 feet deep on this lode, which at a dip of 53° is 1600 feet vertically. This would bring the salt water in at about the same depth as in the Franklin—a little deeper possibly. It should be remembered that the Pewabic lode worked by the Quincy Mining Co. is in the "Ashbed" group, a series of extra feldspathic traps containing unusually much sodium.

The upper water of the Quincy mine is said to have contained 35 parts per million of calcium carbonate and sodium silicate with no free CO_2, reacting alkaline when reduced to half volume.

It is difficult to get the exact vertical distance of these samples as the contours of the ground differ several hundred feet and the lode itself varies in dip from 52° to 54° at the surface to 37.5° at the bottom of No. 2, 5500 feet deep in 1908.

To S. Smillie, then engineer of the Quincy we owe a significant series of tests of the chlorine in the mine water with notes on the copper bearing character of the adjacent ground. The figures are in grams per liter.

No. 7 shaft lies farthest south and was 5,162 feet deep in 1908. It is 860 feet southwest of No. 4 which is 585 feet southwest of No. 2.

In the 13th level, ground carrying no copper............	Cl	.07
In the 16th level, ground carrying no copper............	Cl	1.00
In the 36th level, ground carrying no copper............	Cl	47.25
The well at his house 350 ft. northwest of No. 2 shaft gave.	Cl	0.20

At the 7th and 9th levels near No. 2 which is near the top of the hill in fair copper ground in cross-cuts over to the west vein	0.20
In the large band of barren ground extending down to the 40th level 2300 feet, the chlorine is only	0.07
to	0.14
The water is very copious and abundant, running freely, the ground hard. One drill hole in fair copper went as high as 0.160.	
In the 18th level, No. 2 shaft, the ground carrying little copper, there was	0.04
In the 40th level, No. 2 shaft ground carrying no copper	84.61
In 63rd level, No. 2 shaft, ground carrying excellent copper	175.
In the 64th level No. 2 shaft, ground carrying excellent copper	146.67
No. 6 shaft is 200 feet south of the Old Franklin line. It was 5500 feet deep in June, 1908.	
In the 63rd level, excellent copper ground ... Cl	195.13
In the 64th level, excellent copper ground	146.67

Mr. Smillie also makes the significant observation that deeper down in the mine the amygdaloid belts are much better defined and much less disturbed.

There is in the Quincy a fissure with "dragged copper" and faults (the south side dropped?) running near the west quarter post of Section 26 a little north of east and dipping to the north with a slight hade. The big calcite vein which strikes N. N. W. to the north part of the Quincy shown on the report of the Commissioner of Mineral Statistics for 1889 is not slickensided.

The Mesnard shaft, No. 8 is at the extreme north 4,168 feet north of No. 6 which is 1928 feet north of No. 2, and was 4500 feet deep, the 24th level corresponding to the 42nd level of No. 6. The levels are at 135 feet intervals. From poverty in the upper levels it is said to have improved beginning at the 10th level but markedly at the 20th level, and best at the south end.

In the 13th level, ground carrying no copper ... Cl	1.11
In the 20th level, ground carrying no copper	32.25
In the 20th level, ground carrying no copper	31.75
In the 21st level, drainage, good copper	21.05
In the 23rd level, drainage, fair copper	130.65
In the 24th level, excellent copper	100.30
In the 46th level, excellent copper	147.00

Dr. Koenig made some tests on a deep water from the 47th level of the Quincy running into a sump on the 50th level, given in our annual report for 1903, p. 243, and in the L. S. M. I. paper No. 7.

The Sp. Gr. would indicate 216.27 grams per kilo of $CaCl_2$. We may compute this as:

Cl	132.5
Na	11.7
Ca	64.5
	208.7
Fe	.004
Cu	.009[1]

Ca : Cl = .485

Na : Cl = .0885

This is essentially the same as the water obtained by G. Fernekes from the pump at the 62nd level, and as tested by Geo. E. Steiger, U. S. G. S. Bulletin 330, page 144, and the discrepancies are due to the difficulty of the determining small quantities of other things beside such large quantities of calcium chloride. After running along the level the copper dropped to 7 grams per ton.

Certain of the Quincy samples were tested for CO_2 by distillation, and also for ammonia. A very small amount of the latter was found on which no stress can be laid as it might come from organic contamination or dynamite fuses.

Dr. Fernekes' first test was from drippings in the 49th level north of No. 6 shaft, as follows:

Cl	142.173	grams per liter
Ca	70.072	
Na	12.064	
Br	1.891	
Cu	tr	
Sum	226.206	
Difference	.320	
Total solids determined	226.52	

Sp. G. 1.19

Whence we compute:

Na : Cl = 0.083

Ca : Cl = 0.494

This is practically as strong as it gets.

[1].007 after it has run along the level.

Dr. Fernekes also made the following tests (analyses 89 to 97 of the L. S. M. I. paper) of waters which all had from 8 to 16 mg of copper per ton and are all of the lowest type of water.

From water running from the walls on the 53rd level, north of No. 6 shaft.

Cl	174.287 grams per liter
Ca	86.500
Na	14.068
Br	2.180
Cu	tr.
Sum	277.035
Difference	.465
Total solids determined	277.500[1]

Sp. Gr. 1.21

We compute:

Na : Cl = 0.081

Ca : Cl = 0.496.

Quincy mine. 53rd level N., stream near No. 6 shaft.

Cl	177.380 grams per liter
Ca	87.478
Na	14.920
Cu	trace
Br	2.240
SO_3	.123
Sum	282.141
Difference	.359
	282.500

We compute:

Na : Cl = 0.0843

Ca : Cl = 0.492

This analysis was published by Dr. Fernekes in Economic Geology II, page 584, with a slight misprint.

Quincy mine. In stope 10 feet below 53rd level N. of No. 6 shaft —a running stream.

Cl	173.735 grams per liter
Ca	87.380
Na	13.470

[1]Solids when not heated quite so hot 281.900.

Br	2.272
Cu	tr.
Sum	276.857
Difference	.243
Total solids determined	277.100

We compute:

Na : Cl .078

This sodium ratio is abnormally low—an error in analysis is possible but not probable.

Dripping on 55th level N. of No. 6 shaft, Quincy mine.

Cl	176.027 grams per liter
Br	2.200[1]
Ca	86.478
Na	15.188
K	.411
SO_4	.110
$Si\ O_2$	.020
Fe_2O_3 and Al_2O_3	.010
Mn	.004
Cu	.016
Ni	.006
Sr	trace
Ba	none
Li	none
Mg	.020
B	trace
CO_2	none
Sum	280.489
Difference	.011
Total solids determined	280.500

This is the most complete analysis made of the deep water and may be taken as the standard. It is worth noting that calcium and sodium chlorides form 99% of the total salts, and calcium and sodium bromide three-fourths the remainder.

[1]Cf. test of Dow Chemical Co., .17 per cent or 2.13 grams per liter.

Na : Cl .0865

Ca : Cl .49

N. of No. 6 shaft, running 10 feet below 55th level Quincy mine.

Cl	176.400
Ca	85.200
Na	17.580
Br	2.460
Cu	tr
K	.450
Sum	282.090
Difference	.310
Total solids	282.4

Sp. Gr. 1.22

Boiling point 104°.5 C.

We compute:

Na : Cl = 0.099

Ca : Cl = 0.483

This higher ratio of sodium might be due to urine, etc. A sample at about this level gave the Dow Chemical Co., .17% Br with a Sp. Gr. of 1.293 or 2.190 grams per liter. The same sample gave Fernekes 2.390, which is a pretty close check as bromine analyses go.

Pool with good drainage on 57th level N. of No. 6 shaft, Quincy mine.

Cl	113.7	grams per liter
Ca	57.33	
Na	7.70	
Br	1.2	
Sum	179.93	
Difference	.270	
Total solids determined	180.2	

Sp. Gr. 1.13

Na : Cl = .068

Ca : Cl_2 = .504

59th level, Quincy mine, said to be a fine slow drip.

Cl	166.56
Ca	82.486
Na	13.129
Br.	1.92
Sum	264.035
Difference	1.165
	265.2

We compute:

Na : Cl = 0.0785

Ca : Cl_2 = 0.495

Quincy mine. 62nd level, N. from pump.

Cl	131.46	grams per liter
Ca	65.35	
Na	10.56	
Br	2.004	
Sum	209.374	
Difference	.426	
Total solids determined	209.8	

We compute:

Na : Cl = .08

Ca : Cl_2 = 0.496

In Bulletin 330 of the U. S. Geological Survey, page 144, is an analysis of the water from the "lower level of the Quincy mine, Hancock, Michigan," by Geo. E. Steiger for C. K. Leith. From it we have

Salinity 212.3

Na : Cl = .0885

Ca : Cl_2 = .485

On the whole the analyses of the lower waters are singularly constant in their peculiar composition. The ratio of calcium to chlorine by weight is almost exactly one to two.

When we consider the possibility of admixture from above and from other horizons by cross-fissures, and of contamination in the course of mining operations, the result is the more impressive. The absence of magnesia compared with surface or iron country rocks is the more striking in rocks so chloritic.

The Franklin Junior mine is now running the same Pewabic amygdaloid horizon also a few miles north but not at so great a depth. Water on the 21st level 1000 feet or less north had a Sp. Gr. of 1.010. In the 23rd level the Sp. Gr. was 1.038. A sample was taken, but the vial cracked and most of it leaked out. Ca : Cl was 0.35. In a pool right in the shaft between the 27th and 28th levels it was much over 1.080 (estimated 1.150). Dr. Fernekes tested three samples:

Sample No. 1, 2100′ down on the dip, 1600′ deep is in a cross-cut over from the Allouez conglomerate (See Fig. 40) to the Pewabic lode on which the Quincy mine is working. It was slowly dripping from a seam dipping 50° to S. E., i. e., about at right angles to dip of bed.

The distance from the Allouez conglomerate No. 15 is 192′4 (about 100′ above the Mesnard epidote).

(1) Sp. Gr. by urinometer in mine 1.045. Temperature 61° F. Taken by A. C. L.

Dr. Fernekes determined (on about 30 cc).

Cl	7.912
Ca	2.926
Whence we may compute:	
Na to satisfy Cl	1.764
Sum	12.602
Difference SO_4, Mg. etc	.298
Total solids at 160° C	12.900
Ca Cl_2	8.116
(To satisfy Cl) Na Cl	4.486
	12.602

Na : Cl = 0.223
Ca : Cl = 0.368

(2) Franklin Junior. Dripping from cross-cut on 21st level S. Taken by G. Fernekes later.

Cl	8.580
Ca	3.289
Na	2.349
Sum	14.216
Difference	.044
Total solids determined	14.260

Na : Cl = 0.272
Ca : Cl = 0.384

These two check fairly. It is notable that this which is nearer to the conglomerate is less strong than the next following analysis.

I cannot very well account for the high Sp. Gr. of this and the next, unless we assume that the water gave off little bubbles of gas that clung to the urinometer, which I did not observe or that evaporation tends to very rapidly concentrate the water in the puddles on the floor where the urinometer was floated. The sample was caught in a small vial from the roof.

(3) Another sample was flowing much more freely down the side of the level from a similar seam 386 feet above the Allouez conglomerate and dipping 40° into the foot from the hanging. It must pretty nearly represent the Pewabic lode.

Sp. Gr. 1.055.

	In grams per liter
Total solids at 160° C	46.100
Cl	28.680
Ca	12.290
Whence we compute:	
(To satisfy chlorine Na)	4.45
	45.42
$CaCl_2$	34.09
NaCl	11.33
	45.42

Other substances by difference, SO_3, Mg., etc., .68

Na : Cl = 0.156
Ca : Cl = 0.43

A very small sample from the 23d level, all that was left of a larger sample that had Sp. Gr. 1.038, gave F. W. Durkee:

Cl	45. grams per liter
Ca	15.6
Na	11.8
	72.4

Whence we compute

Na : Cl = .248
Ca : Cl = .212

Evidently comparing this and the Quincy mine, in the Pewabic lode, at any rate, there is vastly more difference in composition between the 15th and 20th levels than between the 21st and the 62nd. See result in 14th level cross-cut. It will be interesting to compare the Allouez conglomerate only 460 feet away.

ALLOUEZ CONGLOMERATE.

On a visit to the Franklin Junior, May 24th, 1906, I found in the 14th level cross-cut 270 feet above the Allouez conglomerate a drip with Sp. Gr. 1.000. The long 4th level cross-cut also had Sp. Gr. 1.000 wherever tested (see Fig. 40).

On the 15th and 16th levels I did not find enough water to test. There was more in the north end of the 15th level and the south end was very dry.

On the 17th level the water on the floor seemed to have Sp. Gr. 1.000.

400 feet north of shaft it was dripping freely and seemed to have increased in gravity (1.002?).

On the 18th level S. a dripping tested had Sp. Gr. 1.000.

At the reservoir for drill water near shaft Sp. Gr. was 1.003.

On the 19th level I could only find a drop to taste—quite salt. The 20th level was dry. The 21st level water of drift has Sp. Gr. 1.003.

The change from fresh to salt was according to Capt. J. Doney between 14th and 17th levels and his observation was later fully confirmed by Fernekes' tests. He also thought the rock became richer at that point.

The Allouez conglomerate has a straighter "hanging" top than "foot" bottom, and where it is thin is is generally barren. There was good copper bearing conglomerate in the 22nd level. Some of the basic pebbles are quite decayed.

The dip flattens from 48.5° down to 46°¾ at the bottom of the mine.

Mr. Rickard in his book on the copper mines of Lake Superior has some notes on the distribution of copper in this lode.

On Oct. 13, 1906, I again visited the Franklin Junior mine.

We failed to get any water at crevices on the 17th and 19th level where Captain Doney had noticed it. Fernekes in 1906, took samples from the No. 1 shaft, on the Allouez conglomerate.

From a drip in the 15th level[1].

Cl	0.416
Ca	0.134
Na	0.115
Sum	0.665
Difference	0.085
Total solids determined	0.750

We may compute:

Na : Cl = 0.277

Ca : Cl = 0.322

The high ratio of sodium to chlorine and of difference not chlorides show the mixture of upper water quite plainly. This is just on the line.

From a dripping 1,000 feet S. of No. 1 shaft on the Allouez conglomerate, 17th level, Franklin Junior.

Cl	0.858
Ca	0.211
Na	0.313
Sum	1.382
Difference	.313
Total solids	1.695

Na : Cl = 0.1382

Ca : Cl = 0.247

This seems to be fresher than that on the same level north. It is said that No. 2 shaft 1200′ S. of No. 1 is better than No. 1 and better than at 1200′ or so than higher up

At the old Rhode Island mine[2] further north and not so rich Mr. A. P. Frapwell found at 1,000 feet, 0.0760 Cl.

Reservoir 100′ north of No. 1 shaft, 17th level on Allouez. Franklin Junior.

Cl	1.066
Ca	0.249
Na	0.404
Sum	1.719
Difference	0.281
Total solids	2.000

[1]Analyses are in grams per liter, parts per thousand unless otherwise stated.
[2]Now part of the Franklin Junior.

Na : Cl .39

Ca : Cl = 0.234

Water dripping 1200 feet S. of No. 1 shaft on 18th level, Franklin Junior.

Cl	3.621
Ca	1.516
Na	0.609
SO_4	0.040
Sum	5.756
Difference	.274
Total solids determined	6.030

This is a *good deal fresher* than the next analysis, the 19th level north, but stronger than the previous one.

Na : Cl = 0.167

Ca : Cl = 0.420

Franklin Junior from a dripping on the 19th level 200 feet north.

Cl	8.320
Ca	3.166
Na	1.750
Sum	13.236
Difference	.224
Total solids determined	13.560

Na : Cl = .21

Ca : Cl = 0.406

From pump on 23rd level near bottom of mine.

Cl	7.540
Ca	2.493
Na	2.032
Sum	12.055
Difference	.295
Total solids determined	12.350

Na : Cl = 0.269

Ca : Cl = 0.330

On the whole the Franklin Junior tests show clearly (1) that the

amygdaloid waters are stronger than those of conglomerate. This confirms the widespread impression of the miner. (2) That the change from fresh to salt is relatively sharp beginning in this case below the 14th level and well established at the 23rd. (3) That the salt water when first struck is relatively high in sodium, and low in calcium, so that no mixture of the strongest water with fresher waters could produce the intermediate waters. We find these inferences confirmed over and over again. (4) That the line between fresh and salt was perhaps higher at the north and leaner end of the Allouez conglomerate corresponding to the surface rise of ground is faintly indicated. A surface launder nearby contained water that gave 0.058 Ca.

Outside the Franklin Junior few tests have been made at or near the horizon of the Allouez conglomerate. I made a test of the Old Delaware mine as it was being pumped out. This is close under the top of the Greenstone and two or three hundred feet above the valley, and was no salter than wells nearby (.030 to .040 Cl).

A sample of water from the 13th level of the Medora shaft of the Keweenaw Copper Company gave

Cl	0.248 grams per liter
Ca	0.151
Total solids	0.560

Ca : Cl = 0.608

This is a hard surface water, the lime mainly that of a hard water. It was still in the upper level. Owing to the flat dip of only 25° or so the mine depth would correspond to only half the vertical distance.

We might assume we had

Na_2SiO_4	0.018 grams per liter
$CaCO_3$	0.150
$CaCl_2$	0.253
$NaCl$	0.143
Total	0.563

CALUMET CONGLOMERATE AND ADJACENT BEDS MIXED.

A good chance to compare tests in amygdaloid and in conglomerate is furnished in the Calumet and Hecla, Tamarack and adjacent mines. A test of water from the Tamarack Pond will be found in the Proc. L. S. M. I., and the report for 1903, p. 78, also one by G. L. Heath from the Red Jacket shaft. This is a vertical shaft and the exact horizon of the water doubtful. The original figures are given there. Computing to uniformity we have the following.

(The water was slightly alkaline, and owing to difficulty in weighing a hygroscopic brine residue like this Mr. Heath thinks the sum of constituents as reliable as total solids, since it is impossible to drive off the water without volatilizing other things.)

Cl	3.2660
Na	1.740
Ca	1.2496
Mg	.0216
K	.0388
Fe	.0026
Cu	.00213
Zn	.0134
CO_3	.149+
SO_4	.0392
SiO_2 dissolved	.0032

Na : Cl = 0.543

Ca : Cl = 0.260

The amount of sodium is relatively very high.

A stronger but yet mixed water derived by tapping the water that had accumulated in the Tamarack Junior mine was given me by Mr. G. L. Heath, July 27, 1905.

This mine was mainly outside the rich shoot of the Calumet and Hecla conglomerate. (Pl. IX). At the east end of No. 2 shaft (See Fig. 37) the conglomerate was only 6 inches of black amygdaloid conglomerate, I am told.

The very small amount of sulphate is noteworthy, and the presence of strontium may be connected with it, for strontium sulphate is but very slightly soluble in salt solutions.

Very rarely barite (and celestite?) are found in the Calumet mine.

Cl	6.421
Na	0.776
Ca	2.875
Mg	.009
K	.019
Fe	.006
Cu	.00144
Zn	.00076
Sr	.01742
Li	.00063
CO_3	.084
SO_4	.001
Illuminating gas	p. n. d.

Na : Cl = .121
Ca : Cl = .448

OSCEOLA LODE.

Prof. James Fisher reports salty water that was popularly supposed to be depositing copper at the 26th level of the old Osceola mine following down the foot.

Tests of waters from the upper levels are given in connection with the Calumet conglomerate, and are all relatively fresh. These were from the Osceola lode back of the old Calumet and Hecla mine.

In collecting the samples from the 30th level cross-cut of Tamarack in connection with President McNair's gravity work, I had a chance to get a sample of water from the Osceola lode. The results are as follows: (See Fig. 37.)

Water from Tamarack mine, 4,300 feet down at 1,794-1,800 feet from shaft No. 2. Taken by A. C. Lane, Sept. 14, 1905. Analyzed by F. B. Wilson—letters of Oct. 8, 9, 28 and Nov. 22.

Sp Gr.	1.135	
Total solids at their melting point.	157,411.5 grams per ton	
Cl	97,963	
Ca	47,166	
Mg	tr	
CO_3	0	
Ba & Sr by flame test on precipitate.	0	
Na	8,278	
K	837	
SO_4	226	
NH_4 Cl by distillation	2,456.7	
NH_4	829.8	
Total determined solids	155,299.8	
Undetermined (organic matter crystal water traces of Fe, Mg, etc.).	2,111.7	
Excess of salts, shortage of Cl, perhaps replaced by organic acids..	1.169	.589

Organic matter leaves a small residue of carbon in the total solids and there is plainly some contamination.

The Sp. Gr. agrees quite well with the total solids. The ratios are:

Na : Cl .0846
Ca : Cl .482

A ratio of Na : Cl like this (cf. Wolverine No. 3 shaft at the 30th level S.) seems to be that normal to the deep waters.

I also made urinometer tests of the waters at other points in the 29th and 30th level cross-cuts but in every case noted they were stronger than 1.060 the limit of the urinometer scale. In particular is this true of water dripping from a winze up to the 29th level, about 400 feet from No. 2 shaft, which seemed to be between 1.08 and 1.16. As reported in Volume V, in the Tamarack No. 3 shaft salt water was struck at 1,267 feet depth (about the horizon of the Pewabic lode) in an amygdaloid horizon much above the C. & H. lode. One of the specimens, too, from Tamarack shaft No. 4 from an ophite close above the Calumet & Hecla conglomerate—No. 16,472, T.4b72, though kept in our collection from 1894 to 1906 was still damp and bitter with calcium chloride.

On July 13, 1909, visiting the North Tamarack shaft No. 3 with Prof. J. F. Paull, I took a sample (No. 7) in the 18th level cross-cut at 790 feet from the Osceola lode again which gave

Cl (Br)	179.5542	per thousand	
Ca	88.582	= Ca Cl_2	245.815
Na	14.893	(14.46 Na=NaCl)	36.782
Sum	283.019	6 H_2O	237.
Total solids at 105°C.	400.	Cf.	519.6

Whence Ca : Cl = .493

Na : Cl = .083

This is somewhat deeper (5223.5 feet vertical) and much stronger but the proportions are the same. The dilution of the 30th level sample is due to contamination. Another small sample (No. 11) from an amygdaloid 50 feet from shaft (hence about 1450 (900) feet from the Calumet conglomerate) in the same cross-cut gave

Cl	.0023mg
Ca	.0010mg

i. e. Ca : Cl = .044

The amount of water was not closely measurable.

A sample of rock from this same lode was extracted four times with distilled water. The sample weighed 851 grams and was not cupriferous. The successive extractions (500 cc. of distilled water were used, except 690 cc. the first time) yielded Dr. A. A. Koch

					Ratios	
					Ca : Cl	Na : Cl
1.	Cl 2.5577 gr.	Ca 1.2414 gr.	Na	.2191 gr.	.487	.086
2.	0.5339	0.2591		.0501	.485	.094
3.	0.3828	0.1866		.0285	.490	.075
4.	0.2283	0.1054		.....	.485	....
	3.7027	1.7925		.2977	....	....

Total actually extracted at least...................... 5.7929

The irregularity in extraction of sodium may be due to solution, but the rock was in coarse pieces, not crushed fine, and was left to soak over night only. The first extraction was as the rock came damp from the mine wrapped in paper bags. I think probably that the total chlorine would be about 4.000, and total calcium perhaps 1.940, i. e. Ca : Cl = .485. If then we assume Na in the water to be 0.360 we shall not be far out. This would make total solids in solution 6.3 mg

The first extraction gave 4.272 (grams solids at 110°) as against a sum of 4.0182, the balance being perhaps crystal water. Part of this may be charged to adherent moisture but I think not much. If the water is as strong as any known (No. 7) and has 180 grams per liter of chlorine (and that is also about the strength of the deep Quincy water) then the 4.000 grams chlorine would mean 22.2 cc. of brine (about 27 grams) of which 20.7 cc. would be water. This would imply about 3.18% of rock moisture by weight, which as amygdaloids are always damp is nothing surprising, or it would mean 22.2 cc. of water to 290 of rock, that is 7.8% of pore space filled with water by volume, which figure should be reduced somewhat for adherent moisture.

The close agreement of the H_2O here found as probably present in the amygdaloid with that we found necessary to convert a fresh basalt glass into chlorite and epidote (Chapter II, § 9, p. 86) is entirely undesigned and accidental, and too much stress should not be laid on it. It is, however, fair to call attention to the apparent presence as quarry moisture of enough water to be a large factor in hydration and chloritization.

A water sample (No. 5) from a winze 650 feet back from the Calumet and Hecla conglomerate is perhaps from the Calumet amygdaloid, but very likely to be contaminated with organic or conglomerate water (to that probably is due the low Ca:Cl ratio) and total solids 360 instead of 400):

Cl	165.5155
Ca	70.8638
Mg	0
Na	not determined
Total solids at 110°	359.6000

Ca : Cl = 0.44

These samples are strikingly like the deep Quincy samples both in proportions and strength, though miles away and in a different group even.

CALUMET CONGLOMERATE.

None of the above analyses represent the pure lower mine water or the Calumet & Hecla conglomerate. They represent either the upper mine waters more or less contaminated with the lower, or other horizons. A sample taken for Prof. H. L. Smyth of Harvard, at 3,000 feet depth, was analyzed by Robert Forsyth. The figures are:

66.94 grams per liter solids of which—

Ca	24.77 %
Mg	0.06
Na	12.14
Cl	61.97
SO_4	0.22
$Si\ O_2$	0.09
Br	.15
Al	.17
Determined	99.57 per cent of solids

Na : Cl = 0.199

Ca : Cl = 0.403

This seems to be more likely the pure conglomerate water.

Another analysis of the Calumet and Hecla mine water from the 24th level, No. 7 Hecla shaft, an inclined shaft on the Conglomerate lode, taken December, 1901, and furnished us by G. L. Heath is as follows:

Total residue in thousand parts of water	.0204
$Si\ O_2$	.0029
Fe_2O_3	.0020
Cu	.00094
Zn	tr.[1]
MgO	.0267

[1] .02 or less.

Na Cl (&Br?)	2.9875
KCl	.0175
LiCl	.0175
CaO (reduce to Ca with trace of Sr)	1.96
SO_3	.1057
Total Cl (and Br)	4.499[1]
Loss on ignition	.5056
CO_3	hardly any[2]
Total solids	7.65610
Difference	.0583

Na : Cl is about 177:450 = 0.26 (distinctly of the middle rather than of the lower type.

Ca : Cl is 0.31

Fernekes took a sample from an inclined winze on the conglomerate lode near Tamarack No. 5 shaft, which gave

Cl	57.550 grams per liter
Ca	25.429
Na	8.032
Br	1.070
Sum	92.081
Difference	.419
Total solids determined	92.500

We compute:

Na : Cl = 0.14

Ca : Cl = 0.443

When we compare these with the previous analyses they agree in being less strong than analyses from the amygdaloids and the ratio of Na : Cl is higher. This agrees with the miner's impression reported by Mr. J. T. Reeder and others, which is confirmed by other tests for chlorine only, that amygdaloid water is stronger than that of the conglomerate.

It is somewhat stronger than Smyth's water at 3,000 feet. The ratio of sodium is lower too. The ratio of Na: Br is about the same.

I also took samples of copper bearing conglomerate and soaked

[1]The poor check in bases (for the chlorine calculated to bases is 4.2833) may be due to the Br.

[2]Corrosive effect about the same as that of the mine water from the Red Jacket or Whiting vertical shaft. Experiments on corrosion showed that there was little effect if the iron was entirely covered with the water, but that otherwise considerable scale was formed on iron pipes.

them in distilled water changed four times. Nos. 1 and 6 in 500 cc. and No. 2 in 250 cc. the first time. No 6 was mainly copper from 20th level of.

		1	2	6
Number		1	2	6
Weight		555 grams	500	242
Cl successive extractions	1.	3.6514	3.4209	.3438
	2.	.4786	.3155	.0482
	3.	.1489	.1064	.0319
	4.	.0851	.0523	.0177
		4.3640	3.8951	.4416
Ca successive extractions	1.	1.773	1.6597	.1357
	2.	.2266	.1442	.0220
	3.	.0882	.0606	.0157
	4.	.0384	.0235	.0063
		2.1262	1.8880	.1797
	=	.487	.585	.41
Na	1.	.2975	.265	
	2.	.059		
Na : Cl	=	1.2 to		18 ? to .09
Total solids in first extraction.		6.750	6.190	.646

It is clear that the Ca : Cl ratio approaches 0.49 in the successive extractions, and that the conglomerate water has at this depth, essentially the same kind of water as the surrounding amygdaloids. But the amount extracted is greater. One may estimate in No. 1 the total chlorine as 4.40

Chlorine	4.40
Calcium	2.15
Sodium	.40
	6.95 grams

or about 1.25% of the rock is soluble solids and probably (if we take water sample 6 below as a key) about 35 cc. of brine, i. e., 42 grams which is to 100 grams or about 7.5% by weight,—about three times as much as the amygdaloids. This would mean about 16.4% of pore space as a maximum. Specimens 1 and 2 came 600 feet from the cross-cut at the northeast end of the 18th level. No 3 was a drop of water only from the shaft at the 19th level, and no tests were made of it.

In the same trip in 1909, above mentioned, I took a sample of mud scraped from a damp spot near the bottom of the mine at the

northeast end about under No. 4 shaft, at the same place that the rock was taken (1); also a sample of mud baled out of a drill hole (2); also some mud from the hanging of the 20th level (4); also muddy water trickling down along foot of inclined shaft at same level very likely to be contaminated (6). These were of value mainly in showing proportions. A. A. Koch obtained

	1[1]	2[1]	4[1]	6
Cl	.716mg.	1.098mg.	.0383mg.	124.784 grams per liter
Ca	.344	.546	.0127	57.111
Na				14.972
Ca : Cl_2	.482	.495	.332	.457
Total solids				255.550

The damp ground is said to be better copper bearing. The main good shoot of copper ground coming in from the Hecla (or "Black Hills") end of the Calumet comes in according to Captain Rosevear in the 15th level at 1300 feet; on the 18th level at 600 feet.

Tamarack No. 4 shaft about 600 feet northeast of No. 3 was much poorer. On the whole the samples (1 and 2) run a little higher in Ca than those at the bottom (6).

I owe to Mr. E. S. Grierson, chief engineer of the Calumet and Hecla, some 33 small samples running about 33 cc. or less, put up in vials I sent. They were mainly tested by Dr. A. A. Koch, but also by Karl S. Meuche, Hore and myself. They include samples from the Kearsarge hole on the Tecumseh (La Salle) and Calumet and Hecla property, the Baltic lode on the Superior property and the Osceola and Calumet lodes. We have the following results on the Calumet conglomerate.

Number	Depth[2]	Position	Cl	Ca	Ca:Cl
1 cc	-1608	90 feet N. of No. 4	3.268 or 2.524	.920	.365
2 cc	-2028	500 feet N. of No. 4	9.571	2.412	.254
3 cc	-1848	2100 feet N. of No. 5	2.127	0.939	.45
5 cc	-1488		2.920K 2.9822L	0.908	,312
Whereas in the amygdaloids we have:					
4 cc	-1668	First amygdaloid east of conglomerate 400 S. of No. 5	55.00K 55.17L	24.907	
6 cc	-472	Shaft 16, 40 feet above 24th level	3.2L		
			3.459	.860	.352

[1]Very small samples result in milligrams not parts. Specimens of rock and water 6 were very nearly from the bottom of the mine at the time, 5367.5 feet deep, where the temperature was 87°. No. 6 has less chlorine than Nos. 5 and 7 and on the whole confirms the miners' impression that the conglomerate has for the same depth less salt than the amygdaloid.

[2]Referred to the level of Lake Superior; + means above, — below.

On the Osceola amygdaloid we have:

10	+850	.071	.004
20	+858	1.418	.008
30	+923	1.064	.014
40	+923	1.418	.014
50	+663	1.418	.004
60	+885	1.418	.031

These show much more strikingly than the analyses at great depth the relative freshness of the conglomerate, which seems also fresher at the north end near the barren ground in that direction. The water from the South Hecla, perhaps at the lower side of the shoot or below is very bad even above the 24th level. It is this region where the salt crystals are found.

Our general conclusion is, then, that the Calumet conglomerate water is relatively fresher than the amygdaloid rocks around it on either side but that this difference seems to disappear somewhat at great depth or at least that the ratio of Ca:Cl becomes about the same. The copper is richest in the middle water and becomes very slowly less rich as the lower water is reached, but continues good long after the lower water is well established, and the Ca : Cl ratio has become 0.485.

KEARSARGE.

Proceeding next in order to a lode where a large number of tests are available we come to the Kearsarge lode, and we take the analyses in order from the north end.

The Ojibway struck salt water quite early, it is said, at 500 feet (the 4th level). In opening the upper levels some fine specimens of crystallized cubes and dihexahedra of copper are found. One specimen Hubbard showed me has copper upon, and later than, quartz prisms and pyramids, then later yet a zeolite in white prisms with oblique terminations supposed to be laumontite.

The Mohawk mine was tested by Fernekes as follows:

Shaft No. 1, 10th level dripping.

Cl	.357 grams per liter
Ca	.067
Na	.154
Sum	.578
Difference CO_3, SiO_2, etc.	.122
Total solids determined	.700

Na : Cl = 0.43
Ca : Cl = 0.183

This is a typical upper level water like the S. Kearsarge, but only half as strong.

Shaft No. 1, 11th level, Mohawk dripping.

Cl	.285
Ca	.057
Na	.1198
Sum	.4618
Difference	.1382
Total solids determined	.600

Na : Cl = 0.42

Ca : Cl = 0.20

Note how sharp the change is at the next level.

Shaft No. 1, 12th level Mohawk dripping.

Cl	3.172
Ca	.993
Na	.914
Sum	5.079
Difference	.276
Total solids determined	5.355

Na : Cl = 0.294

Ca : Cl = 0.314

This is fairly in the middle zone. The sodium ratio is dropping.

Shaft No. 1, Mohawk 13th level, pool.

Cl	3.299
Ca	1.241
Na	.711
Sum	5.251
Difference	.349
Total solids determined	5.600

Na : Cl = 0.216

Ca : Cl = 0.282

Shaft No. 1, Mohawk, 20 feet S. of 14th level, dripping.

Cl	21.546 grams per liter
Ca	10.560
Na	1.824
Br	.124
Sum	34.054
Difference	.346
Total solids determined	34.400

Na : Cl = .085

Ca : Cl = 0.48

This is quite characteristic of the lower zone in proportions if not in concentration.

The features of a splitting of the copper of the lode is, I am told, shown in the Osceola lode on the Calumet property. Near the margin of the amygdaloid there is always a little copper, then again in the foot where it is more massive, more irregular and perhaps 30 feet away.

The Kearsarge lode in various mines including the Pewabic has an east vein and a west vein. How far is this in a way the same phenomenon? The Osceola lode seems to run from 11 to 19 lbs. of copper per ton, *in selected* parts.

In this mine, the amygdaloid has two forms of alteration, one brown and soft, one hard, greenish gray, quartzose and epidotic. Cross-fissures contain Mohawkite and Keweenawite. Shaft 2 is especially poor, and on the whole the rock is not as rich as in the Ahmeek, or in the Shafts 5 and 6 near the Ahmeek, and the rock near them is of the grey, not the brown type. The intersection of the nearly vertical fissures with the lode which dips 36° or so, inclines 50° to 80° to the north. They seem to guide somewhat the shoots of copper.

H. V. Winchell was inclined to believe these Mohawkite veins genuine fissure veins filled from below. The cracks in which they occur are certainly of that nature.

The North Kearsarge directly abuts the Ahmeek and is deeper than the Mohawk. From this we have Fernekes' test (L. S. M. I., Vol. XIII, analyses 117 to 120).

North Kearsarge mine. 26th level, 700 feet S. of No. 3 shaft.

Cl	83.400
Ca	38.667
Na	9.826
Cu	p.n.d.[2]
Br	.905
Sum	132.798
Difference	.202
Total solids determined	133.000

Sp. Gr. 1.099
Ca : Cl .465
Na : Cl .118

This is much stronger than any of the Wolverine waters but the Na : Cl ratio is similar to that on the 26th level.

N. Kearsarge, 300 feet S. of No. 3 shaft, on the 27th level.

Cl	71.240
Ca	31.822
Na	9.822
Cu	p.n.d.[2]
Br	.945
Sum	113.829
Difference	.371
Total solids determined	114.2

Sp Gr. 1.089
Ca : Cl .457
Na : Cl .1375

This is less strong than 119 at the N. end or than No. 117 on the level above, but has just about the same amount of sodium.

[1]All samples from N. Kearsarge are estimated to contain from 2 to 8 mg per liter of copper.
[2]Estimated from 2 to 8 mg per liter.

N. Kearsarge 450 feet N. of No. 3 shaft, 27th level.

Cl	76.363
Ca	32.937
Na	11.597
Cu	p.n.d
Br	.725
Sum	121.622
Difference	.178
Total solids determined	121.800

Sp. Gr. 1.091

We compute:

Ca : Cl .43

Na : Cl .151

These are running a good deal higher in sodium than the Wolverine at the same levels and concentration.

N. Kearsarge, 28th level, 150 feet S.

Cl	60.480
Ca	25.618
Na	9.722
Br	.675
Sum	96.495
Difference	.245
	96.740

Sp. Gr. 1.074

Na : Cl = 0.161

Ca : Cl = 0.425

As we go south from the Allouez gap the relative amount of sodium at about the 26th to 28th levels seems to decrease, the calcium to chlorine ratio increases, perhaps, but it is notable that it is lowest in this last analysis—the only case of the sort I have met.

Adjacent to the North Kearsarge is the Wolverine. It is on the Kearsarge lode but there have been a number of exploratory crosscuts. See Chapter V.

The Sp. Gr. of the water (at 48° F.) in the
8th level cross-cut was 1.000 by urinometer;
13th level cross-cut was 1.000 by urinometer;
17th level cross-cut was 1.017 by urinometer;

The sample from the 17th level was tested by F. B. Wilson with the following results:

Sp Gr.	1.022
Cl	15.2287 grams per liter
Na	2.731
Ca	6.300
Mg	.013
SO_4	.0724
Sum	24.3451

Na : Cl = 0.181

Ca : Cl = 0.413

This total agrees with Sp. Gr. which I found.

This agrees pretty closely with Fernekes' tests at the 20th level south, Wolverine No. 3.

At the 24th level (possibly some water working down through the slopes) Sp. Gr. was 1.012 by urinometer, and in the 29th level cross-cut 1.033.

The sharp change in the composition of the water in the Wolverine at the 17th level as at the Franklin Junior is clear. G. Fernekes made additional tests as follow:

Wolverine No. 3 shaft, 300 feet S. on 20th level.

Cl	17.395
Ca	7.321
Na	2.852
Sum	27.568
Difference (Mg, SO_4, etc)	.252
Total solids determined	27.82

Sp. Gr. 1.021

Na : Cl = 0.165

Ca : Cl = 0.42

Wolverine No. 3 shaft, 300 feet S. on 22nd level, drip.

Cl	11.705
Ca	5.071
Na	1.784
Sum	18.560
Difference	.800
Total solids determined	19.360

Sp. Gr. 1.015

We compute:

$Na : Cl = 0.153$

$Ca : Cl = 0.433$

This is apparently somewhat diluted of the same type as above.

Wolverine No. 3 shaft, 300 feet S. on the 24th level, dripping.

Cl	33.640
Ca	15.600
Na	4.088
Br	.868
SO_4	.130
Sum	54.326
Difference	.174
Total solids determined	54.5

Sp. Gr. 1.039

We compute:

$Na : Cl = .122$

$Ca : Cl = 0.463$

The lowest water is nearly established. Note as compared with the other levels the sudden rise in solids, almost double, while the sodium ratio drops.

This is about the same concentration as the 30th level Centennial, No. 108 of the L. S. M. I. paper.

Wolverine No. 3 shaft, 300 feet S on 26th level, dripping.

Cl	55.765
Ca	26.800
Na	5.912
Br	.930
Sum	89.407
Difference	.393
Total solids determined	89.8

Sp. Gr. 1.071

We compute:

$Na : Cl = 0.106$

$Ca : Cl = 0.48$

This is the lower water.

Wolverine No. 3 shaft, drip 300 feet S. on 28th level.

Cl	75.231
Ca	36.347
Na	7.367
Br.	1.085
Sum	120.030
Difference	.270
Total solids determined	120.3

Sp. G. 1.092

We compute:

Na : Cl 0.098

Ca : Cl = 0.483

Wolverine No. 3 shaft, 300 feet S. on 30th level dripping.

Cl	64.390
Ca	31.271
Na	5.756
Br	.940
Cu	p.n.d.
Sum	102.357
Difference	.143
Total solids determined	102.5

Sp. Gr. 1.079

The last three are of nearly the same kind of water varying slightly in concentration. In this:

Na : Cl = .0895

Ca : Cl = 0.485

The varying concentration may be partly due to evaporation and partly to very recent circulation of fresh water incident to the mining.

The Centennial 30th level water is about as strong as the Wolverine 24th level water and the Na : Cl ratio is the same.

Centennial mine. At the 11th level "no shaft" was reported, i. e., not enough to make analysis on a small sample. Fernekes estimates that a gallon would have been needed.

At the 13th, 15th and 20th levels.

	13	15	20
Cl	1.711	3.549	5.780
Ca	0.626	0.880	1.880
Na	0.389	1.287	1.584
Sum	2.726	5.716	9.244
Difference	0.232	0.264	0.216
Total solids determined	2.958	6.0	9.460
We compute respectively:			
Na : Cl =	0.228	0.357	0.275
Ca : Cl =	0.368	0.248	0.326

At the 25th level it is much stronger, and the Ca : Cl ratio gets above 0.40. The lower water is well established.

Cl	27.114
Ca	11.6
Na	4.22
Cu	p.n.d.
Sum	42.934
Difference	.266
Total solids determined	43.200

We compute:

Na : Cl = 0.156

Ca : Cl = 0.428

Centennial 30th level.

Cl	34.263
Ca	15.700
Na	4.140
Cu	p.n.d.
Sum	54.103
Difference	.377
Total solids determined	54.480

Na : Cl = 0.121

Ca : Cl = 0.457

Note that the most rapid rise in saltness comes between the 20th and 25th levels. Later tests of Centennial waters came through E. S. Grierson.

Mark	Depth	Cl	Ca	Location and remarks	Ca:Cl
1 c	-1128	53.53	24.90	27th level, 200 feet north of No. 2	.465
2 c	-1191	59.202	26.52	28th level, 200 feet south of No. 2	.448
3 c	-1252	58.493	26.34	29th level, 100 feet north of No. 1	.456
4 c	-1328	68.064	29.46	30th level, 200 feet south of No. 1	.43
5 c	-1409	77.99	36.50	31st level, 300 feet north of No. 1	.47
6 c	-1487	84.371	40.16	32d level, 200 feet north of No. 1	.475

The two shafts are close together but diverge going down. No. 2 is the farthest north. This set, later than Fernekes, is much stronger. Is it a question of evaporation of the water before or after it was taken as a sample, or is a stronger water actually coming in from the wall rock? I think the latter is quite probable. The earlier tests were not as strong as those at the Wolverine at the same depth, but the last set are quite as strong.

South Kearsarge No. 2 shaft, 9th level, drippings collected by F. W. McNair and C. D. Hohl.

Cl	.842
Ca	.111
Na	.418
Sum	1.371
Difference	.61
Total solids determined	1.432

This is essentially a duplicate of the next. Cf. the 10th and 11th levels Mohawk.

Na : Cl .495
Ca : Cl .132

South Kearsarge No. 1 shaft, 9th level, dripping collected by F. W. McNair and C. D. Hohl.

Cl	.702
Ca	.0912
Na	.414
SO_4	.075
SiO_2	.035
Fe_2O_3 / Al_2O_3	.030
Sum	1.3472
Difference	.0028
Total solids determined	1.350

This is a complete analysis intended to show the character of the middle water in the upper levels, before the calcium chloride becomes conspicuous, though even here there is chlorine, which may be considered combined with calcium. There is even here little or no CO_2 and the Ca is not abnormal for any water.

Probably the iron and alumina may exist as chloride.

(Fe_2O_3 = .030) = (Fe = .021)

We have:

Na : Cl		.58
Ca : Cl		.13

We may combine this as

Water glass Na_2O 4 SiO_2	= .0067+.0023+.034	= 0.044
Salt Na Cl	= .4083+.630 Cl	= 1.038
Fe Cl_3	= .021 +.039	= .060
Ca Cl_2	= .019 +.033	= .052
Ca SO_4	= .0312+.075 SO_4	= .106
Total Ca combined	.0502	
Ca combined with CO_2?		.041
		1.3411

Note the tendency to alkalinity, both in the water glass and the excess of lime. The sodium is more than could be obtained by dilution of a deeper water with a surface water.

From the Calumet shafts 19 and 20 on the Kearsarge we have no tests. They were barren and did not go deep. Small samples from No. 21 shaft, through E. S. Grierson gave A. A. Koch

Number	Depth	Cl	Ca	Ca:Cl	
1 K	556 A. T.	.177	.018	.010	9th level, 20 feet south of fissure
2 K	427	.213	.025	.012	100 feet below 10th level
3 K	347 A. T.	.675	.110	.015	10 feet above 12th level as strong a stream as drill hole No. 10

These show the middle water just coming in. This shaft is on the whole richer than No. 19 or 20 (or the south part of the Centennial?). At about the 10th level a considerable flow of water came in under a seam and the lode was thought to be better.

The next property south is the La Salle. From the Tecumseh No. 1 shaft we have the following tests of the Kearsarge lode.

Mark	Depth	Cl	Ca	Ca:Cl.	Notes on location
1 T	At 900 feet,	.035	.004		71 feet south, 9th level
2 T	At 1010 feet,	.052	tr		300 feet south, 10th level
3 T	At 1120 feet,	.071	.014		40 feet south, 11th level
4 T	At 1230 feet,	.142	.004		174 feet south, 12th level
5 T	At 1340 feet,	.177	.012		69 feet south, 13th level
6 T	At 1450 feet.	.248	.185		in the shaft itself.

These waters with their very great softness are largely the upper water,—like the South Kearsarge but containing less salt. They show in their rapidly increasing chlorine a steady admixture of lower water. On the whole, however, the La Salle has not been rich and the shafts farther south, the so-called Caldwell shafts, have shown even less stamp rock. On the Franklin Junior the Kearsarge was cut in a cross-cut at the 4th level, but very close to the surface and the water was of course, fresh.

The next lower horizon from which we have many tests is that of the Isle Royale-Arcadian lode. An analysis of surface water from the Arcadian shaft is given in the annual report for 1903, page 243.

Isle Royale Consolidated Mine. Arcadian, i. e. Isle Royale amygdaloid epidote, and possibly Grand Portage lodes. This is close to Portage Lake just back of Houghton, and is 400 feet or 500 feet above it, i. e. above Lake Superior. It is the old Huron mine re-opened. This went down about 16 levels or 1000 feet.

On the Grand Portage lode shafts to 500 feet were sunk. This opened on many levels by cross-cuts, but is about 200 feet (above) west of the Isle Royale lode on which the shaft is sunk.[1] This is worth mentioning since dripping from the levels might well have been affected by surface water standing in the levels a good while.

300 feet N. of No. 2 shaft 15th level, dripping. (Cross-cut to Portage lode at 14th level?)

Cl	9.204 grams per liter
Ca	4.321
Na	.994
Sum	14.519
Difference	.581
Total solids determined	15.1

Sp. Gr. 1.007 low!

We compute.

Na : Cl = 0.0925 Ca : Cl

This is a dilute deep water.

[1]N. B. This is not on Isle Royale but back of Houghton.

18th level, dripping, 300 feet N. of No. 2 shaft.

Cl	34.920
Ca	16.751
Na	3.058
SO_4	.179
Cu	p.n.d.[1]
Sum	54.908
Difference	.792
Total solids determined	55.70

We compute:

Na : Cl .089 Ca : Cl

This is a typical dilute deep water.

19th level, N. of No. 2 shaft, from a pool from dripping.

Cl	45.178
Ca	22.201
Na	3.837
Br	0.320
SO_4	.234
Cu	p.n.d.[1]
Sum	71.770
Difference	.330
Total solids determined	72.1

Sp. Gr. 1.057

We compute:

Na : Cl .085 Ca : Cl

Dripping 50 feet S. of No. 2 shaft on 20th level.

Cl	7.626
Ca	3.249
Na	1.204
Cu	p.n.d.
Sum	12.079
Difference	.241
Total solids determined	12.32

Sp. Gr. 1.009

[1]Estimated 2 to 8 mg per liter.

Here is lower down a distinctly weaker water with

Na : Cl .158 Ca : Cl

The contrast between this and that above at the 5th level is worth noting. Though they have about the same strength the deeper water is in one case diluted with fresh water that has found its way rapidly and directly down, while in the other case there is much sodium, presumably derived by decomposition of the rock.

The 21st level was the bottom of the old Huron mine on the same lode (2500 feet deep) shafts 6 and 8, of the Report of Commissioner of Mineral Statistics for 1888.

WINONA AND KING PHILIP MINES.

These waters were tested by Dr. M. L. Holm in connection with the Challenge waters. They are distinctly salt at the 5th and 8th levels respectively. They are newly opened compared with the Mass and Adventure. On the whole the water appears to be weaker to the north which is the poorer end. Winona shaft No. 2 farther north was of little value for 200 to 1000 feet though there was some copper rock in the 6th level south and Shaft No. 3 was poor on the 3rd and 4th levels, but improved from the 7th to 12th levels. All the drifts north to No. 4 shaft are said to be in poorer ground. In that direction we seem to find the upper type of water exclusively while only one, that is that from King Philip shaft No. 1 at the 8th level is the lowest type. This is said to be particularly good in copper from the 6th to the 9th levels. This is brought out by arranging the analyses thus:

Winona No. 3 shaft, levels north	3	4	6
Number of analysis	429	422	424
Chlorine	tr	tr	100

Ratio Ca : Cl more than 1, i. e., surface waters in a region of hard water. Limestone Mountain is not so far off, but here the glacial movement was from the northwest over the traps which are limey.

No. 3 shaft levels south..	5	7	8	9	10
Number of analysis.	423	425	426	427	428
Chlorine	2.050	.225	.125	.250	.300
Ratio Ca : Cl......	.13	.427	.39	.42	.40

No 423 is evidently abnormal, urine contaminated?

King Philip No. 1 shaft levels..	5	6	7	8
Chlorine	.406	.900	2.85	15.25
Ca : Cl_2..................	0.29	0.29	0.3	0.45

The Mass and Adventure mines of Ontonagon county are at about the horizon of the Winona lode.

Prof A. P. Frapwell, then assistant in chemistry at Ann Arbor, 1906-7, was with us in the summer, and I had him make the following tests with the U. S. G. S. field assay outfit. The Ca runs from 19 to 60, though the results are not very reliable. The same comment applies to SO_4 determinations, as the electric cells were old. Still that would tend to give SO_4 too high, and we may be sure that SO_4 is at least as low as the low figures shown.

The water of the Mass mine, C shaft, for the first thousand feet was fresh and down to and including the 8th level gave him the result below, and water from a seam on the 17th level gave (analyses 50 and 46 of the L. S. M. I. report):

	8th	17th
Cl	.050	22.476
Ca (hardness as)	.082	.044?
Alkalinity as Ca CO_3	.263	.015?
Alkalinity as Na_2 CO_3	.000	.021
SO_4	.110	.135
Sp. Gr.		1.041

They are said to have lost their copper when they struck salt water. In the A shaft a seam in the 10th level gave water with only

Cl	.006
SO_4	.038
Ca (hardness)	.016
Alkalinity as Ca CO_3	.225
Alkalinity as Na_2 CO_3	.000

This is distinctly an upper water, but it must be remembered that the mines are old and circulation started by mining operations may have a great effect. He also made tests of the Adventure mine of water down to the 6th level in No. 1 shaft (54), the 8th level in No. 4 shaft (51), the 12th level in No. 3 shaft (56) also of the Michigan mine B shaft, of the water down to the 10th level (50). They are all very fresh and run between 30 and 6 parts per million of chlorine. He also made a number of tests of surface waters, tabulated in the L. S. M. I. paper.

Victoria mine, Rockland district. A sample was taken by Dr. L. L. Hubbard from the 19th level cross-cut, about 600 feet from the shaft near the top of the "Forest" conglomerate. It is from prac-

tically the same location as No. 20 taken only three years before. It gave

Cl	3.159
Total solids	6.465
Sp Gr.	1.004

Additional samples were collected late in 1908 by Mr. Schultz and myself and tested with the following results. See Figure 60 in Chapter VIII.

Mr. Schultz suggests that there may be more calcite in the upper levels, more epidote in the lower, just as in the Baltic mine, epidote comes only in depth. At any rate the Forest conglomerate in the 19th level is full of epidote. If the carbonate radical does replace the chlorine of $Ca\ Cl_2$ in the upper levels, it would leave chlorine ions to travel and attack the rock.

1.	4th level cross-cut north from seam at about 45° dip and strike a little more north.	Cl 0.013
2.	Five paces from breast	Cl 0.015 Ca 0.030 H
3.	East end of 4th level in shattered lode	Cl 0.025
4.	From percussion drill hole a little north of shaft, 12 paces east of Plug 132	Cl 0.028
6.	Floor of west end 4th level	Cl 0.003
8.	5th level west near Plug 156	Ca 0.033
9.	5th level west, quite a fair flow which blackens the rock, from a cross-seam dipping to southwest, five paces east of Plug 158.	
10.	6th level east, 10 paces west of Plug 161, slow drip into bottom of level.	Cl less than 0.017
11.	6th level west, near a seam 5 paces west of Plug 176 where there is a drift to north.	Cl less than 0.066
12.	West end of 6th level, in this level it was mainly dry.	Cl less than 0.188
	In the 7th and 8th levels it was dry to the east.	
13.	East 10 paces of Plug 24 steady stream	Cl less than 0.007
14.	A slow drip from a west dipping seam 6 paces east of Plug 31	Cl less than 0.014
	Location is supplied from an underground reservoir in the 4th level	Cl 0.102

The 10th level was dry.

15. The 12th level east had a very slow drip about 800 feet from the end near a plug. This continues as a bar of damp ground, with slow drip nearly to the shaft. Cl 0.019
Ca 0.010 to 0.021
Hardness 0.030

Then to the shaft and the first few hundred feet west it was very dry.

16. Sample from 12th level west and beyond fault; water hole; very slow drip Cl 0.051
Ca 0.075

17. From end of 14th level, a water hole in damp, much broken ground. Cl 0.102
Ca 0.013 to .028
Hardness 0.035

The 15th and 16th levels were dry.

18. Under a seam with flatter dip than bedding, slow drops about 50 feet from east end of level. Cl 0.110
Ca 0.172

19. From a slow drip not at the clay seam but farther on in a cross-cut north. Cl 0.128
Ca 21.45 or 50

20. From 19th level cross-cut just under heavy trap, at 460+78. Cl 2.920 or 2.140
Ca 0.830
Hardness .810

21. On a seam at 1260 which dips with the formation Cl 3.550
Ca 3.00

22. At 510 north of the lode Cl 0.660
Ca 0.060

23. At a stub drift Cl .500
Ca .100

25. In the 22nd west Cl 10.640
Sp. Gr. 1.012
Ca .960

26. In the 22nd east Cl 7.400
Ca 1.440

In its freshness down to the 12th level to which point was a lively circulation, in the dry zone then succeeding (the 15th and

16th levels, for instance) from which the salt water may have drained off, and in the distinctly salt water at the 19th to 22nd levels this mine is typical. The lode is not an amygdaloid but a shattered zone in the foot of a trap. On the whole the copper is supposed to be best from the 11th to 14th levels, thence making west. To the east there is a cross-fault, the east side thrown 50 feet south.

TESTS OF THE BALTIC LODE.

This is the lowest of the lodes worked. It lies between a conglomerate (the Baltic conglomerate) as it is generally called (No. 3) and a heavy ophite, known as the Mabb ophite, whose mottles are up to 7 mm. across. The distance above the conglomerate varies, but is about (150) feet more or less, and it is (170 to 200) feet below the ophite. It is no one well-defined amygdaloid top to a flow but rather an impregnated shear zone or stockwerk, copper being found over a belt more than 40 feet wide.

The Baltic lode is the lowest horizon much worked.

In tests at the Isle Royale section 12 shaft I found only fresh water. Only a few nuggets of copper were found, looking almost like boulders,—residues of solution and redeposition perhaps. The rocks were full of reddened clay slips and wet. See Fig. 45 and description in Chapter V.

The set of samples of waters gave the following (by field tests) results, which by checks on Yale No. 2 and T. 3 are somewhat low.

No.	Location	Cl	Ca
1.	About 117 feet in, in west cross-cut drip..	.007	.012
2.	About 300 feet in, in slow drip..........	.005	.001
3.	About 360 feet in, in fast drip..........	.005	.000
4.	About 450 feet in, in fast drip, 15 feet from end	.005	.000
5.	30 feet from end of east cross-cut, very slow drip	.298	.019 to .041
6.	Conglomerate in the east cross-cut..........	.030 .025	tr. .003.-6
7.	20 feet above it..........................	.035	.001-2
8.	Diamond drill hole, free flow..............	.142	.012-25
9.	Diamond drill hole 3, free flow............	.028	.001-6
10.	Diamond drill hole 1, free flow............	.277	.022-47

These are all characteristic soft upper waters, none as strong as at the Superior. The calcium is only so much as might consist with sodium silicate.

At the Superior shafts next south No. 1 shaft was reported notably salty at the 2nd level and has shown better copper ground, of the same class as at the Champion Copper mine. This, as shown in the map (Pl. X) is about 1200 feet south of the north line of Section 15. Samples gave

Mark	Cl	Ca	Ca:Cl	Location
1s	.674	.014	.048	5th level 500 feet south of No. 1
2s	3.510 3.297	.855		5th level 660 feet north of No. 1
3s	2.482	.462	.13	6th level 230 feet south of No 1
5s	5.318	1.430		7th level 110 feet north of No. 1
6s	1.129 1.114	1.753		

This is plainly salter to the north, and to the south in No. 2 and the Atlantic the workings are both very fresh and poor.[1]

No. 2 is about 2540 feet southwest of No. 1 and showed no good ground, until the 600-foot level, and then in the north drift. It is nearer the disturbed zone of Atlantic section 16.

The Atlantic mine on Section 16 was in a much faulted and disintegrated zone, full of clay slips in which the surface water seemed to have penetrated far.

The Baltic comes next up the slope.

The Baltic water appears to be fresher than the Trimountain. The drift covering was much thinner, the bed rock surface higher and the lode on the whole richer.

At the 4th level was a "red" water, probably swamp colored. The 6th level cross-cut (now Atlantic at the north end) was very fresh. There is a fissure dipping south from Shaft 4 at the 4th level to Shaft 3 at the 14th level and when the fissures were struck surface wells of the town went dry. The character of the ground and the amount of copper according to Capt. M. Tretheway, changes in crossing the fissures. On the whole a greenish tone of rock rather than a brown amygdaloid is thought better, quite different from the feeling at the Mohawk, but I think it is a chlorite green rather than an epidote green.

---

[2]But see analysis in appendix.

Baltic mine. 15th level. Dr. Fernekes reports:

Cl	27.264	
Ca	13.682	
Na	1.929	
Br	0.3112	
Sum	43.187	
Difference	.813	(CO_3 or SO_4)
Total solids	44.000	

Na : Cl .073

The ore contains considerable sulphur and arsenic.

We may compute:

$CaCl_2$ 38.	Cl=	24.3
$NaCl_2$ 3.79,	Cl=	2.946
NaBr .402,	Br=	.312
Na_2CO_3 . . 2.3		
44.492		

Trimountain. On a visit to the Trimountain mine of the Copper Range Company, Sept. 4, 1906, I took a sample of salt water from 200 feet N. of shaft No. 3 S. 9th level in a lean streak of rock that comes under a cross-seam which dips about 45° to the south. Salt water is reported even as high as the 6th level North of No. 3 from a drill hole in the hanging wall.

The Sp. Gr. as estimated in the mine was 1.078 at the mine temperature, probably about 51° F.

Dr. Fernekes found, Sept. 8, 1906.

Sp. Gr.	1.053	(=65.8 $CaCl_2$)
Total solids	74.44	parts per thousand
Cl	46.02	
Na	3.36	
Ca	24.58	
SO_3	.484	
Fe, Mg, CO_2	tr.	
Sum	74.444	

We may compute:

NaCl	8.54
$CaCl_2$	63.90
$CaSO_4$	.823
Excess of Ca combined with CO_2 in part	1.28
	74.543

Na : Cl .076

Ca : Cl .535

These values are so abnormal that one is tempted to suspect an analytical error.

A larger less strong sample taken for and tested by Dr. Fernekes was perhaps of the water of the drift as a whole as follows:

Trimountain 9th level.

Cl	19.874 per thousand
Ca	9.000
(to satisfy acids) Na	2.653
Br	.243
	31.770
Diff.	.230
Total	32.000

Na : Cl = 0.133

Ca : Cl = 0.453

On the whole the Trimountain has been much poorer in copper than its neighbors north and south. The south end of the Trimountain, a compact light gray quartz epidote rock, was poor and the north end of the Champion, Shaft B, is not so good as the south end where E shows excellent ground.

In the upper levels of the Champion, at least as I visited it in 1901 and 1909, the copper was in lumps, sometimes richly, but not associated with prehnite, and while the rock was amygdaloid it was not markedly so, being more an amygdaloid trap at the foot of a marked amygdaloid. Some fine specimens of iceland spar came from the 6th level east, and selenite crystals three inches wide and ten inches long occurred in the 13th level east, being the last formed, the order of growth being chlorite, epidote, calcite in half inch dog-tooth spar crystals, then gypsum.

Whitneyite ($Cu_9 As_2$) occurs on the 3rd level. Chalcocite (Cu_2S) occurs in seams parallel to, not across, the strike, but both sulphides are supposed to be superficial. On a visit in 1909 (Aug. 4) I collected samples from the 13th level. It was reported that the water at the 7th level E shaft was quite drinkable.

A sample representing the water pumped and collected between the 6th to 12th levels gave A. A. Koch:

	No. 20
Cl	3.4564 grams per liter
Ca	1.5523
Na (computed)	.45
Sum	5.46
Total solids[1]	7.850

Whence

Ca : Cl = 0.45

Na : Cl = 0.13

On the 13th level we had tests of a sample of wet mud (No. 21) and of a (No. 22) water from a pool 50 feet on under drops from the roof that showed a refraction equivalent to Sp. Gr. 1.10 which is about what the analysis calls for

	No. 21	No. 22
Cl	.1879 milligrams	59.556 grams per liter
Ca	.0933 "	28.560
Na (computed)		93.8
Sum		126.25
Total solids[1]		153.9

Whence

Ca : Cl = 0.496

Na : Cl = 0.08

It is quite clear that whereas No. 21 is pretty nearly the pure type of lowest water, the others are mixed.

GLOBE EXPLORATION.

The Copper Range Company took an option on this land the next mile south of the Champion. The overburden was heavy (356 feet). While the diamond drill is said to have shown encouraging copper values, exploration to a depth of 1000 feet showed so little that the option was surrendered. Three small samples were sent by Agent F. W. Denton, April, 1908.

[1]At 110°C, including crystal water.

No.	1	2	3
Location	6th level		
Depth	855 625	only 4 cc	
Cl	3.55	6.0	
Ca	2.?	2.26?	1.8?
Ca : Cl	0.56?		
Sp. Gr. by J. W. Holm	1.004		
Sp. Gr. by urinometer	1.008		
Index of refraction	1.56	1.59	

Challenge exploration of St. Mary's Mineral Land Co. (Fig. 59.) The Challenge mine at the 3rd level at about 700 feet from the surface is distinctly saline.

The index of refraction is also distinctly greater than that of pure water, and corresponds to a specific gravity somewhere about 1.015. The sample was not, however, so taken as to be free from possibility of urine contamination.

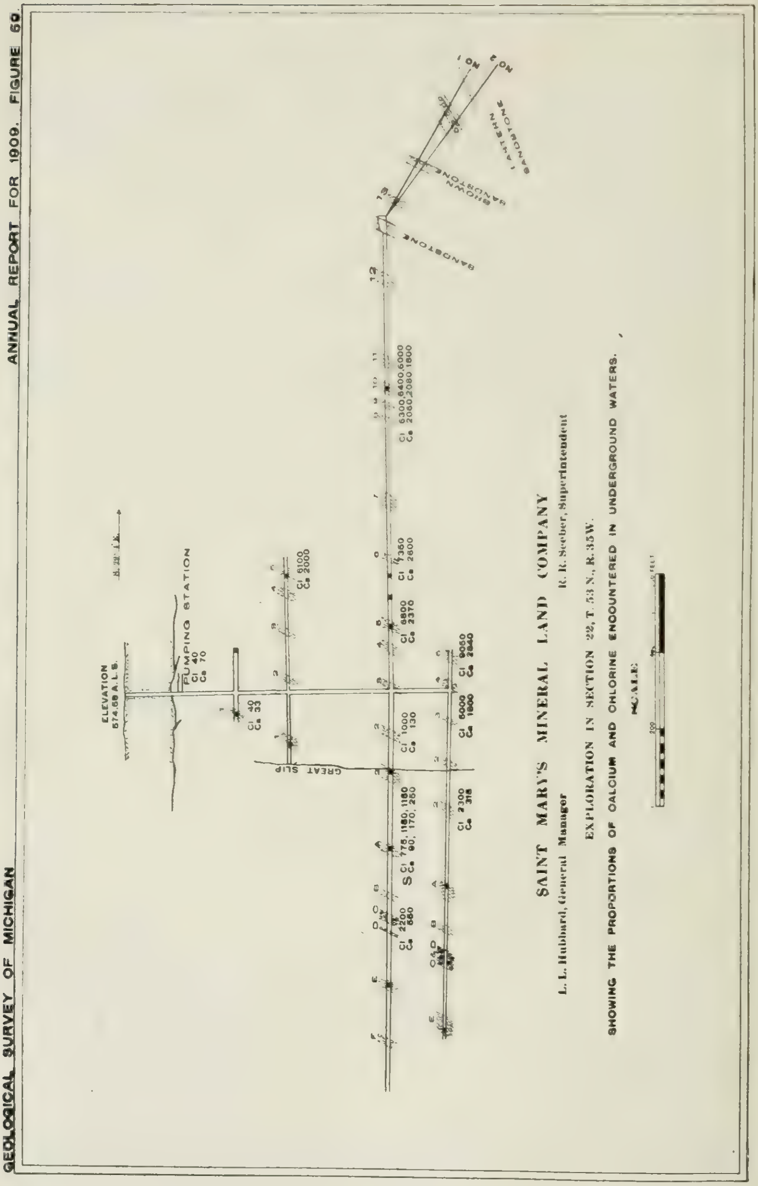

Fig. 59. Challenge exploration of St. Marys Company with the concentration of the mine waters plotted thereon.

A sample, very salt, from No. 9 vein east cross-cut had Sp. Gr. 1.009 to 1.012

Cl	6.600		
Ca	2.882	Ca Cl_2	7.881
Alkalinity as Ca CO_3	.004	Ca CO_3	.004
SO_4	.080	Ca SO_4	.120
Na (computed)	1.010	Na Cl	2.569
	10.576		10.574
Total solids (ignited)	10.362		

Ca : Cl = 0.437
Na : Cl = 0.149

No. 7 vein in the east cross-cut gave poor field tests Cl 3.48+?
F. B. Wilson found Ca .232+ (?2.32)
refraction equivalent to Sp. Gr. 1.015

This agrees well with a later test, but is not on the Baltic lode perhaps. (See Fig. 59.)

Dr. M. L. Holm, State Bacteriologist, kindly made additional tests of the Challenge explorations. His report follows.

Lansing, August 31, 1908.
Laboratory Dept.

Dr. Alfred C. Lane, State Geologist, Lansing, Michigan:

Dear Doctor—In submitting this report on the series of mine waters received August 28th, it will be necessary to outline briefly the methods employed in the analysis, in order to make these results intelligible for your interpretation.

These samples, consisting of from 10 to 25 cc. each, would not permit the use of any of the standard methods of analysis, as we have no standard methods adaptable to so small a quantity. It therefore became necessary to devise special methods for this particular series in order to get the greatest possible accuracy with the least possible quantity of water, since only such very limited qūantities were at hand.

The chlorides, reported in terms of Cl., were determined as follows,—50 cc. of distilled water was placed in a 200 cc. flask and carefully sensitized, K_2CrO^4 indicator was added and 2 cc. of the mine water was run in from a carefully graduated pipette. This was then titrated with a standard solution of $AgNO_3$. If the 2 cc. did not require sufficient quantity of standard solution to permit of accurate reading, more mine water was added in 2 cc. quantities until sufficient was used to allow for a fairly accurate reading.

In cases where the limited quantity of water was not sufficient to require an amount of standard solution for reasonably accurate reading, the quantity of chlorine was reported as "trace."

The H_2S was next determined by placing a drop of the mine water on a filter paper prepared by moistening in a 10% solution of lead acetate and dried. Where sufficient H_2S was present to produce a distinct brown color of PbS, the H_2S was designated as plus (+), and as the color deepened, more plus signs were used to indicate the increased quantity. Where no coloration of the PbS paper occurred, the H_2S was designated as minus (—). Several of these waters contained an appreciable quantity of precipitated sulphur and yet no H_2S. It is probable in these cases that the sulphides had decomposed.

The water samples were next acidified with HNO_3 to dissolve all calcium present as carbonates, and filtered. A carefully measured quantity, ranging from 5 to 20 cc. in each case, or as much as the size of the sample would permit, was then taken, made alkaline with NH_3 and precipitated with $NH_4C_2O_4$. This precipitate, of course, would bring down, together with the calcium, any quantity present of iron and aluminum. The last two named elements would, of course, not appreciably affect the results where the quantity of lime was large, but where the quantity of lime was found to be very low, the interference of these elements, iron and aluminum, must be considered in interpreting the results. The precipitate was next carefully washed with distilled water and titrated with $\frac{N}{10}$ $KMnO_4$ After the titration, 10 cc. of 5% KSCN was added, and where sufficient quantity of iron was present to give a distinct coloration, the same was determined colorimetrically, as shown in the report. Where sufficient quantity of iron to give distinct coloration was not present, iron was designated as minus (—).

The following is the report on the various samples of water submitted with their findings:

	Chlorine.	Calcium.	Hydrogen Sulphide.	Iron.
	parts per	million		
Challenge mine.				
No. 406, Pump Station	40.000	70.000	—	—
Depth No. 407, 1st level, 1st vein	40.000	33.000	+ +	—
No. 408, 2nd level, 5th vein	6,100.000	2,000.000	+	—
No. 409, 3rd level, veins C & D	2,200.000	550.000	—	—
No. 410, 3rd level, 1st vein. Drift S. No. 3 x cut	775.000	90.000	+ + +	—
No. 411, 3rd level, 1st vein, No. 1 x cut South	1,150.000	170.000	+ +	—
No. 412, 3rd level, 1st vein	1,150 000	250.000	+	—
No. 413, 3rd level, 2nd vein	1,000 000	130.000	+ + +	—
No. 414, 3rd level, 5th vein	6,800 000	2,370.000	—	—
No. 415, 3rd level, 6th vein	7,350.000	2,600.000	—	—
No. 416, 3rd level, 9th vein	6,300.000	2,060.000	—	—
No. 417, 3rd level, 10th vein	6,400 000	2,080.000	—	—
No. 418, 3rd level, 11th vein	6,000.000	1,800.000	—	—
No. 419, 4th level, 2nd vein	2,300 000	315.000	—	—
No. 420, 4th level, 3rd vein	5,000 000	1,800.000	—	—
No. 421, 4th level, 4th vein	9,050.000	2,840.000	—	—
Winona mine.				
No. 422, 4th level, No. 3 shaft	Trace	160.000	—	5.000
No. 423, 5th level, 3 Shaft S	2,050 000	260.000	+	3.000
No. 424, 6th level, 3 Shaft N	100 000	120.000	+	10.000
No. 425, 7th level South	225 000	106.000	—	—
No. 426, 8th level S. 3 Shaft	125 000	320.000	+	6.000
No. 427, 9th level S. 3 Shaft	250 000	106.000	+ + + + +	—
No. 428, 10th level S. 3 Shaft	300 000	120.000	+	10.000
No. 429, 3rd level N., 3 Shaft	Trace	53.000	—	1.000
King Philip Mine.				
No. 430, 5th level, No. 1 Shaft	406.000	120.000	+ +	5.600
No. 431, 6th level, No. 1 Shaft	900 000	260.000	—	—
No. 432, 7th level	2,850.000	853.000	—	1.300
No. 433, 8th level, No. 1 Shaft	15,250.000	6,820.000	—	—

Respectfully,

M. L. HOLM. M. D., Bacteriologist.

F. W. SHUMWAY. M. D., Director.

Very noticeable here is the fresh water found near the great fault, nearly a strike fault, shown in Figure 59, which is thought to have displaced lodes A and 1, while the other veins 3 to 11 have about 6 per thousand of chlorine and perhaps show the normal salinity. Evidently, however, even at this moderate depth we have the middle and not the upper waters. The lodes 3, 4, 5 and 7 all showed some copper, almost an encouraging amount.

The following are some additional field tests (not reliable). The Nonesuch mine water in September, 1908, has about .016 Cl., .043 (Ca Mg), .065 CO_3 when Iron River just above, not leaking in had .029 Cl, .030 (Ca Mg), .045 CO_3.

SURFACE WATER.

These above are mine waters proper. In my annual report for 1903 and in Volume XIII, Proc. L. S. M. I., will be found many analyses of surface waters which have an interest in discussing the

problem of circulation. We need not repeat them all here. From them I derived as a normal surface water analysis in the copper country, in grams per liter.

Cl	0.0035
Ca	0.019
Mg	0.004
Na	0.0023
$Si\ O_2$	0.010
CO_3	0.040
SO_4	0.006
$(Fe\ Al)_2\ O_3$	0.0015
	0.0863

WATER FROM DRILL HOLES AND WELLS.

In a few cases (more of late) samples been obtained from flowing and other drill holes. They are, of course, free from mine contamination.

Freda. Dr. Koenig also made some tests of the water of a deep well put down in the Freda sandstone at Freda by the Copper Range Co., which, with the record of the well, are given in the 1903 annual report, page 165. It is worth remembering that this is by the side of Lake Superior, five or six miles from the traps of the main copper range in the formation which I have concluded to call the Freda sandstone, the western sandstones of some writers, the Upper Keweenawan of Irving. The well all the way down was in red sandstones, red clays, and fine grained conglomerates, with a good proportion not only of felsites but of grains of more basic rocks. Computing the figures in ions we have:

Cl	40.42
Na	7.60
Ca	16.04
Mn	.57
Mg	.03
K	.30
Br	.21 to .35[1]
	65.17

Na : Cl = 0.173

Ca : Cl = 0.396

Sp. Gr. 1.051 or 1.049

[1]Midland Chemical Co.

It is worth noting that the much deeper wells at Lake Linden in the Jacobsville sandstone are not reported to have struck any salt water and the analyses (1903 report, pp. 163-164), show only a few. 52.69 parts per million of salt (sodium chloride). It is said, however, that the 1200′ well at Grand Marais struck salt water and calcium chloride springs at Whitefish Lake are described in the report for 1908, page 18.

A well at Pickford put down in 1907, which reaches down into the Potsdam sandstone and has a heavy flow of water below 1,000 feet, probably at about 1,400 feet, gave Prof. F. S. Kedzie

Na Cl	0.5148
Ca CO_3	0.2029
Ca SO_4	0.075
Mg CO_3	0.0038
Si O_2	0.0072
Difference	0.061
Total mineral constituents	0.9647

This would give us	1		2
Cl	0.320		.304
SO_4	0.053		.120 to 50
			.167
Ca	0.103		
Mg	0.030		.072
CO_3	0.196	Hardness	.115 to
Si O_2	0.007		.321
Na	0.195		

Field assay tests on a nearly similar sample gave the results of column 2.

A drill hole (No. 10) put down by the Calumet and Hecla (Fig. 36) was very soft. Tests gave

Cl	0.016	say	.0257 Na Cl
Ca	0.0126	say	.0334 Ca CO_3
Na	0.014	requiring	.0009 Na CO_3 or silicate?
SO_3	tr	trace Na_2SO_4	

$$Ca : Cl = 0.79$$
$$Na : Cl = 0.87$$

This is a characteristic upper water as there is not enough chlorine to combine with the sodium, to say nothing of the calcium, yet after all it is so weak that we can not suppose the middle waters made by a mixture of it and the lower water. It is notable

that in presence of sodium in excess the amount of calcium carbonate is just above that of saturation when no bicarbonate is present.

On the other hand a salt water has just been struck in South Lake drill hole No. 2, Section 31, T. 51, R. 37, which is said to have deposited copper on the rods. It came from shortly above 2348 feet depth. It gave Dr. Koenig the following results:

$Ca\ Cl_2$	11.66%
$Na\ Cl$	1.24
$Fe_2\ O_3$	tr
SO_4	tr
Mg	0
Sp. Gr.	1.1097

Whence

$Cl = 84$ per thousand

$Ca = 42$

$Na = 5$

$Na : Cl = 0.084$

$Ca : Cl = 0.50$

This is a pure lower water in ratio, diluted perhaps by some remnant of the water used in drilling.

Near by, Belt mine drill hole No. 5 flowed freely nearly one cubic foot a minute (T. 45° F.) and the flow is probably below 127 feet, between 112 and 180 feet vertically. There was found

Cl	0.264
SO_4	0.082
Hardness as Ca	0.024
Alkalinity as Ca	0.010
With CO_3	0.015
Alkalinity as Na_2	0.014
With CO_3	0.018

$Ca : Cl = 0.01-$

Its softness relative to the chlorine is characteristic of the top of the middle water which is evidently high.

A well in the Freda sandstone, I believe, put down by the Greenwood Lumber Company at Green, west of Ontonagon, only 1000 feet from the shore of Lake Superior and 100 feet above it yielded it is reported

$Na\ Cl$	.06
$Ca\ Cl_2$	.04

This like the Freda well is so related to the main range that one might expect artesian conditions which might force (in case fissures were present) salt water up from the underlying Keweenawan. Mr. Weidman also informs me that the salt water reported by A. R. Schultz from the "Potsdam" at Osceola[1] is really from the underlying Keweenawan. Whether the salt licks such as are listed in my report for 1908 derive their salt always from cross-fissures and are thus a sign of faults remains to be seen. They indicate something abnormal. For instance, Union Springs in the Porcupine Mountains has only 3 milligrams per liter chlorine and about 45 of CO_2 but not far off on Section 22, T. 51 N., R. 42 W. is a salt lick.

§ 6. WIDE SPREAD CHARACTER OF THE CALCIUM CHLORIDE WATERS.

We have already called attention to the fact that calcium chloride water occurs not only throughout the Copper Country, in the iron country, in all the ranges and at Whitefish Lake and Pickford which is at the eastern end of the Upper Peninsula, but they are world wide. Numerous analyses of such waters will be found cited in my previous papers. I give as examples here one or two which came to my attention in the current year (1909). Dr. M. L. Holm made for me an analysis of the Fischer well, Mt. Clemens as follows, in grams per liter.

Fe	.002
Al	.182
Mg	4.481
Na[2]	34.338
NH_4	.103
Cl[3]	94.785
SO_3	.585
S	.304
CO_3[4]	.126
Ca[5]	16.4
Sp. Gr. at 15.5° C	1.11
Ignited solids	148.380

Ca : Cl = .174

This may be combined for geological purposes as follows:

[1]U. S. G. S. Water-Supply Paper 114, p. 240.
[2]Including potassium, but this was very low.
[3]Bromine 0 by comparison of gravimetric and volumetric tests.
[4]Directly determined, being precipitated as lime water.
[5]Strontia 0.

		Molecular proportion.	
$Fe\ H_2\ (CO_3)_2$ ..	.006	.000035	
$Al_2\ Cl_6$	.893	.00335	
$Mg\ Cl_2$	19.052	.200	
$Na\ Cl$	87.263	1.493	
$NH_4\ Cl$	.305	.057	
$Ca\ Cl_2$	39.981	.3515	
$Ca\ SO_4$	.809	.0061	
$Ca\ S$	.684	.0095	
$Ca\ H_2\ (CO_3)_2$ ..	.162	.0010	
$Ca\ O_2\ H_2$.......	3.100	.0419	
	151.275		
Substract Volatile solids			
H_2S	.323		
$NH_4\ Cl$	.305		
CO_2	.092		
H_2O of $Ca\ O_2\ H_2$	.755	1.509	
Result		149.766	non volatile solids? to be compared
with		148.38	actual residue

It is possible that a little Na Cl goes over on ignition, but there is also oxidation of the iron and alumina and transfer of any chlorine supposed to be combined with them to the calcium and probably other changes to be allowed for. It seems to me probable that a perfectly fresh deep-seated water of this type would contain enough S to convert all the calcium hydrate shown to calcium sulphide. The H_2S escapes in bubbles as the water rises in the well, leaving an alkaline water. While this water contains calcium chloride, however, it differs widely from the Copper Country waters, and notably in the greater amount of magnesia and sulphur contained.

In Chapter IX will be found references to analyses of calcium chloride from Chili, from New Jersey and from Germany.

§ 7. GASES IN ROCK AND WATER.

The only scientific investigation of the gases in the rocks and mine water is that of R. T. Chamberlin[1] who found that on heating the core at 524 feet, Franklin Junior drill hole No. 3 there was driven off

[1]Gases in Rocks (1908) pp. 20, 33-34.

	H_2S	CO_2	CO	CH_4	H_2	N_2	O	Ratio volume of gas to volume of rock.
First heat.................	0.00	1.31	.09	.09	2.34	.05	0	3.88
Second heat six months later	0.00	1.33	0.08	0.03	0.43	0.05		1.92
Third heat one week later...	1	0.53	0.12	0.00	0.12	0.02		0.79

These gases Chamberlin thinks are partly due to reactions in heating, of ferrous minerals and those containing water, partly to occlusion or possibly decomposition of carbides, very little to inclusion in actual cavities. But it is worth noting that inflammable gas was found in the Silver Islet vug and in the Tamarack Junior mine water, and that on unwatering the Old Delaware mine a gas explosion took place.

Moreover, Capt. W. Wearne told me that on unwatering the old National mine in Ontonagon county at about the 40th level he was burned from a pocket of gas in the roof of a stope and that there was some gas in the old St. Clair when the Phoenix opened it up, but he had never seen gas in a new mine, and that in unwatering an old mine there was always a water line marked on old stopes and drifts showing where gas had been confined above the water. My general impression would be that the gas was produced from the reaction of water on the rock, most likely on the ferrous salts therein.

§ 8. DISCUSSION.

No one can be more painfully conscious than I of the uncertainties of all the mine water work. Uncertainties that arise from human contamination seem not to be as serious a source of error as I feared but account for certain discrepancies. Uncertainties, also, arise from defects in analyses and evaporation of the small samples which alone it was practical to take. But the greatest source of error may be the circulation which is consequent on the mining operations themselves. We can never be sure that we are dealing with the water that belongs at a given level and lode and not water that may have followed down recently from above on the one hand or come in from the wall rock on the other hand. In fact as we go through a copper mine the damp places where there is real dripping are the exception. Had I but realized sooner that by soaking the rock one can get a solution strong enough to analyze we could have had better systematized results. As it is, I place very little reliance on any particular sample of water being characteristic of the bed in which it is supposed to occur or the exact

depth at which it is supposed to come. While the summary of results given in § 2 above will be found, I think, firmly established by the mass of evidence, yet there are interesting points that need farther investigation.

In these copper mine waters, beginning at the top, we see a prompt and practically complete elimination of the magnesia which we found in other regions in the chloride and in the surface waters. This may be associated with the occurrence of secondary chlorite, replacing even felsite in the Calumet and Hecla boulder and other secondary minerals like prehnite.

Near the surface and in the zone of vadose, that is circulating, waters, the ratio of lime to chlorine is very irregular, sometimes high and sometimes low. See, for instance, the upper analyses at the Winona, etc., by Dr. Holm. This is, however, only where the chlorine itself is very low and we presumably have a mixture of hard surface water. As we get to the bottom of the circulating waters, however, the ratio gets low, not merely because the chlorine is greater but because the lime is less. See, for instance, the analyses from the Tecumseh and South Kearsarge. This may be due to the fact that we are free from the influence of water percolating through calcareous drift, or it may be due simply to the less solubility of carbonates than bicarbonates, the extra carbonate molecule being lost in presence of sodium slicate, precipitating calcite and silica, leaving sodium carbonate in solution. The alkaline reaction of some of the waters suggests this.

But then, rather suddenly as we strike the middle water, sometimes as in the Baltic lode close to the rock surface, again as in the Franklin Junior, as deep as the 17th level, we find the concentration and calcium to chlorine ratio both rising suddenly. Within a few hundred feet the ratio Ca : Cl becomes over 0.4, but thereafter it rises but little and I doubt if it ever exceeds 0.49, the few analyses which go more than that being perhaps inaccurate. The ratio 0.483 which is just the ratio which would indicate a salt $Ca_3\ Na\ Cl_7$ is approached within the limit of accuracy (when we consider that Br is often included with chlorine and is often over one per cent of the latter) in a great many cases. But I can find no reference to any such salt or any solution of this constant composition, either in Van Hoff or Hahn, nor any known chemical reason why the calcium chloride water might not be stronger. Indeed Hahn's tests on evaporation brines point to a practically complete elimination of the sodium where the calcium magnesium chloride solution reaches a concentration of about 370 per thousand. So we

are thrown back upon the supposition that this ratio was that of the connate water that pervaded the formation. But is this proportion inherited from an early ocean? I once thought so, but this could not be if the Keweenawan was a land formation.

Is it due simply to a tendency to equilibrium in presence of the containing rock?

Then should it not vary more than it does in soda and lime melaphyres, and sandstone and conglomerate? There is, to be sure, some sign of difference here and perhaps a slow ionic migration tending to bring all the water to the composition which is in equilibrium, will account for the facts. Or are we to look to some Keweenawan "Great Salt Lake" which determined the ratio?

As to circulation producing these waters (1) the surface waters pick carbon dioxide near the surface and after they have dissolved enough to satisfy these acid radicals, they are soon saturated, and have relatively little solvent power further. It increases, of course, slowly as they warm up, and they might attack silico-chlorides in glass. But analyses of hot springs of circulating water show no such percentage of salt as we have here.

Against the idea that downward working surface waters pick up sodium chloride to become salt, and then later add calcium chloride we have independent of chemical arguments two lines of facts. The order of attack of the traps, as microscopic thin sections show, is that lime and magnesia minerals are earlier attacked than those containing sodium and moreover, the hydrous lime secondary minerals, like prehnite, epidote, and laumontite precede the sodium minerals, which are confined to the upper levels.

(2) No simple upward circulation of the calcium chloride water can explain the facts, for water cannot dilute itself. Suppose, however, we assume that there are two types of water concerned, one buried with the strata and that there has also been water circulating or sucked in from the surface, we still have a number of different possibilities to consider.

(3) How far have the waters been concentrated by hydration, absorbing part of the water and leaving the rest stronger? This is certainly a factor, as the computations of Chapter II, pp. 84-87, show quite plainly.

(4) How far can the excess of sodium in the middle waters be accounted for by supposing that the upper circulating waters toward the lower range of their action not only dissolved more, but lost more by hydration thus producing a stronger water, which mixed with the lower waters might account for the middle waters?

A study of the analyses even at several hundred feet depth of waters like those at the Medora shaft Kearsarge No. 21, etc., shows that so long as there is really active circulation, absorption of the water by the rock does not tend to increase the strength half so much as actual solution of rock material. The waters change in composition, bicarbonates becoming less, chlorides more important, sulphates going in and out but remaining very fresh compared with the deeper type. Even in much reddened and hydrated rocks the waters are fresher rather than stronger. Compare those of Isle Royale, Section 12 with those of the Superior mine nearby.

(5) How far are the middle waters to be explained by ionic migration, the sodium silicate or carbonates of the upper circulating water zone being caught by the calcium chloride and precipitated as calcium silicate or carbonate while the sodium chloride remains in solution?

This is certainly a factor of importance. Yet it seems to me that if this were all, the border line between the fresh circulating, and the deeper waters would be sharper than it is. We should have calcium silicate common instead of rare. For the calcium aluminum hydrous silicates actually formed we must look to reaction with the rocks as shown in § 2.

The theory that explains all the facts seems to me more complex. It assumes original (connate) water and circulating (vadose) water, and it assumes that both are sucked in and react with the rock and with each other. As one of the products of these reactions is copper, further discussion may be put off to the next chapter.

CHAPTER VIII.

THE FORMATION OF COPPER.

§ 1. THE ARTIFICIAL PRODUCTION OF COPPER.

It will be convenient to repeat here a brief account of some experiments by Dr. G. Fernekes then of the Michigan College of Mines, now of Pittsburg, in which he succeeded in forming copper from chloride solutions such as the mine waters.

DR. FERNEKES' EXPERIMENTS IN ARTIFICIAL PRODUCTION OF COPPER.

These he has already described.[1] We may sum up his work, modelled after Stokes,[2] in a diagram as follows:

		To water in sealed tube were added
Cold water jacket around upper end.	18-inch tube of glass filled with water and sealed.	Solution of ferrous chloride $FeCl_2$ nearly neutral with sodium carbonate. Few crystals potassium bromide KBr. .2 gram cuprous chloride Cu_2Cl_2
Lower end in sand both at 200° C. to 280° C.		5 grams calcium hydrate CaO_2H_2 or " carbonate $CaCO_3$ or " silicate $CaSiO_3$ or prehnite H_2O. $2CaO$. $2Al_2O$. $3SiO_2$. or datolite " " , B_2O_3, $2SiO_2$. in fine powder.

Dr. Fernekes then describes the following reactions as taking place.

hotter end.	1. $2\ FeCl_2 + 2\ CuCl_2 = Cu_2Cl_2 + 2\ FeCl_3$ 2. $2\ FeCl_2 + Cu_2Cl_2 = 2\ Cu + 2\ FeCl_3$ 3. $FeCl_3 + 2\ H_2O = Fe\ (OH)_2\ Cl + 2\ HCl$.	cooler end.

Now in Stokes' experiments in unequally heated solutions like this sulphate instead of chlorides were used,[3] so that his equations were:

[1] Economic Geology, 1907, pp. 580 ff (II, No. 6, Sept.-Oct).
[2] Economic Geology, 1906, pp. 644 (I, No. 7, July-August).
[3] Economic Geology, 1906, p. 644 (I, No. 7, July-August).

hotter end.	4. $2\,CuSO_4 + 2\,FeSO_4 \rightleftarrows Cu_2SO_4 + Fe_2(SO_4)_3$ 5. $Cu_2SO_4 \rightleftarrows CuSO_4 + Cu$	cooler end.

hotter end	6. $Fe_2O_3 + 3\,H_2SO_4 \rightleftarrows 3\,H_2O + Fe_2(SO_4)_3$	cooler end.

There is another experiment by Stokes[1] of interest to us, to-wit:

hotter end.	7. $AuCl_3 + \overset{\text{ous}}{3\,Cu\,Cl} \rightleftarrows Au + \overset{\text{ic}}{3\,CuCl_2}$	cooler end.

We may apply this to the silver which we find most in the upper levels on, and later than, the copper. While silver chloride is quite insoluble it is soluble enough in these strong chloride solutions for the following reaction slowly to go on.

hotter end.	8. $AgCl + CuCl \rightleftarrows Ag + CuCl_2$ 9. " $+ FeCl_2 \rightleftarrows$ " $+ FeCl_3$	cooler end.

Now, as Dr. Fernekes remarked, the copper shown in equation 2 did not appear as such (because it would be attacked and re-dissolved by the HCl set free by reaction 3) until a neutralizing agent was added (eq. 10).

Possibly in nature electric currents or very great length of tube and slow action might take the place of such an agent, but there was one obvious reaction suggested by the geological conditions we were trying to imitate. (In nature the copper is persistently associated with calcium carbonates or silicates and often deposited on corroded surfaces of calcite.) This was the neutralization of the acid (H Cl). This was successful, first with calcium hydroxide CaO_2H_2, then with $CaCO_3$, then with calcium silicate in the form of powdered wollastonite. Copper was deposited within 10 to 15 minutes heating at 200° C. Complete precipitation took a longer time.

Sodium carbonate was also used.

We may add then to the three reactions 1-3 above one more.

$$10.\quad 2\,H\,Cl + Ca\begin{cases} O_2H_2 \\ CO_3 \\ SiO_3 \end{cases} \rightleftarrows Ca\,Cl_2 + 2\begin{cases} H_2O. \\ H_2CO_3 \\ H_2O + SiO_2 \end{cases}$$

The above reaction worked freely and rapidly; the copper came down in a fluffy mass.

[1]Loc. cit., p. 650.

To obtain it crystallized it seemed natural to use a less soluble neutralizing agent. The following minerals occurred to me from the geological conditions as especially worth trying:

Labradorite $Ab^1\ An^1$ to $Ab_2\ An_3$

$(Na_2O, Al_2O_3, 6\ SiO_2 + 1$ to $1.5\ (2CaO, 2\ Al_2\ O_3, 4SiO_2)$

Prehnite, $H_2O, Al_2O_3, SiO_2 + 2\ (CaO, Al_2O_3, SiO_2)$

Laumontite $4\ H_2O\ (CaO, Al_2O_3, 4\ SiO_2)$

Datolite $H_2O, 2\ CaO\ B_2\ O_3\ 2\ SiO_2$

Pectolite $(Ca, Na_2H_2)\ SiO_3$

Analcite $2\ H_2O\ (Na_2, Ca)O, Al_2O_3, 4\ SiO_2$

Labradorite and laumontite gave no results. As a matter of fact neither are intimately associated with copper, the labradorite occurring in the fresh unaltered trap, and the laumontite, though a secondary zeolite, being notoriously a bad sign for copper, though at times pseudomorphs of copper after laumontite do occur.

On the other hand prehnite and datolite both gave positive results, and both frequently occur in nature colored pink with finely divided copper. Capt. J. Vivian had a wonderful collection of flesh colored datolites. Datolite nodules are often coated with copper.

The tubes were heated intermittently, for 10 hours a day, the heat removed in the evening, and again applied the next morning.

After heating the solution and prehnite in this manner five days an explosion took place at about 250° C. A portion of the side of the tube about 5 cm from the bottom that is *at the hotter end*, was blown off, leaving a cake of mineral underneath, which could be seen under a hand lens to be interspersed with shiny particles of crystalline copper. That they were such was proved by tests.

The prehnite had become much darkened, and the particles of the mineral were *stained red with iron oxide.*

Datolite was acted on in a similar manner for six days at the end of which time minute crystals of copper could be detected throughout the mass of the mineral.

It is profitable to consider the reactions from the point of view of electro-chemistry and ionic dissociation. There is this extra justification for this that experiments by J. M. Longyear and W. W. Stockly have shown measurable differences of electric potential near lodes, and abnormal magnetic variations are not uncommon. In fact from the almost northerly direction of the main shoot of the Calumet and Hecla deposit and the great sensitiveness of copper to electricity it has been suggested that certain electric currents were the determining factors in its deposition. There is

some indication not only that the copper in the Calumet and Hecla shoot pitches north, but that other beds beneath are enriched in a band or zone across the formation, whose borders run north and south. The general course of the Calumet and Hecla conglomerate shoot is shown on Plate IX. The west line is nearly north and south as shown, though a rich spot or two has been found outside,—one at 7000 feet in South Hecla. To the south in less than nine miles it changes its character becoming a basic amygdaloid conglomerate, and in one of the Tamarack Junior shafts which mark the other side of the shoot it was only six inches thick and black.

Schematically we may express the reactions above in terms of beginning and final products.

II. $2FeCl_2 + 2CuCl + 3CaSiO_3 = 2Cu + Fe_2O_3 + 3SiO_2 + 3CaCl_2$.

That this reaction, which is only a slight modification of that suggested 30 years ago by Pumpelly is really *schematically* one by which native copper has been formed seems to me almost conclusively proved by the facts:

1. Dr. Fernekes has shown that it actually takes place.

2. The end products are actually the common products of the veins, *and the most abundant constituent of the mine water.*

It is understood that the calcium or sodium silicate is really in more complete molecules and goes into more complex molecules, and that similarly the ferric iron and silica may go into other molecules like epidote. Finally instead of ferrous chloride there may be some ferrous silicate, for it is important to remember that we combine as end products what are really probably extremes in a chain of reactions that we have to consider, which end products may be a good deal separated in space.

Another interesting series of experiments are those of E. C. Sullivan in Bulletin 312 of the U. S. Geological Survey on the interaction between mineral and water solutions. The points which seem to me of importance are that the feldspars tend to produce alkaline solutions and that orthoclase and a whole string of silicates tend to take copper from its (sulphate) solution. But native copper was not formed nor involved in the reaction, which (and this is of especial importance) goes on only in an alkaline solution.

Another of these Bulletins (49) by Frank K. Cameron and James M. Bell on the action of water and aqueous solutions on soil carbonates is of interest especially in showing the solubility of calcium carbonate in sodium chloride and gypsum, being a maxi-

mum at about 40 grams per liter of Na Cl, being less for greater and less concentrations. This will explain ready migration and solution and precipitation of calcite in the zone of middle waters. Lime is more soluble in sodium chloride than in pure water (Table XL[1]) and also it is relatively soluble in hot strong solutions of calcium chloride (Table XLIII, loc. cit.) so that it may readily be precipitated from cooling solutions of the deep waters.

§ 2. REACTIONS OF ROCK AND WATER IN THE KEWEENAWAN.

We have then only slight modifications to make to adapt the results of Fernekes to the conditions under which copper occurs in the Keweenawan rocks, this great series of ancient lavas separated either by originally porous scoriaceous lava tops or agglomerates or ordinary sediments.

Whether deposited beneath the sea or on land is not really essential to the argument. The pores would be filled with water or gas. Chlorides are associated with lavas and enclosed in them is glass.

It seems safe then to assume that some of the conglomerates and some of the amygdaloids were filled with water—and it also seems safe to assume that this water contained some chlorides, even though not so great a ratio as at present. When the next lava flow would come over it it would be heated. But the amount of heat given off at once would be but a small proportion of that which existed in the lava flow, as lava is a poor conductor and quickly chills at the surface while the interior remains hot. In fact one can walk on the surface while yet the interior is so hot that a walking stick thrust into a crack bursts into flames and the cracks produced by contraction and cooling show a dull red heat.

As I have elsewhere pointed out[2] in case of lava flows 240 feet thick there is some reason to think that it may be 20 or 30 years before consolidation at the center was finished and that it was nearly 10 times as long before the temperature at the center would drop to say 100° C.

In the meantime no doubt many other lava flows might have come. Much of the heat of the lava would probably escape upward, and since the specific heat and heat of evaporation of water is very great, and the diffusivity of lava small, the water in the underlying beds might or might not be turned to steam.

We had then at the close of the Lower Keweenawan period a

[1]Of Bulletin 49 above cited. See also Bull. No. 92: The Effect of Water on Rock Powder by A. S. Cushman.

[2]Annual report for 1903, p. 248. See also Chapter VI § 6.

series of many thousand feet of lavas containing here and there streaks of hot water or vapor. These hot waters attacked the lavas and produced the chlorite and zeolites so characteristic of the melaphyres. The first products of these reactions may take up more room than the original minerals. Olivine changing to serpentine and magnetite Van Hise[1] cites as giving an expansion of 30 per cent. And for a change of augite to chlorite, epidote, quartz, and hematite[2] an expansion of 8.58 percent is estimated, and most of the changes of the albite and anorthite molecules to minerals of the zeolite group are also changes which produce expansion, though few of them are directly applicable to our problems. But I have given above a change producing copper in which there is no expansion (pp. 84-87).

The net result of this first work must also have been that much of the water was absorbed. The deepest and freshest specimens of the traps are hydrated and chloritic, so that what water remained was relatively stronger in chlorides. There may also have been some exchange of bases, but the older and deeper seated secondary minerals produced by alteration do not contain sodium and in sections of trap from diamond drill cores the feldspar is often quite fresh. The olivine and then the augite alter first. What sodium was absorbed, if any, most likely came from the glass. The chlorine does not come in any of the secondary minerals formed and so must have accumulated and was[3] either originally present in the water or in the silico-chloride glasses. But calcium carbonate which is insoluble in hot water, is found everywhere and to all depths and chlorite and epidote are equally wide spread among secondary minerals. Thus since calcium occurs also in the glasses it would not be safe to venture any guess as to the original amount of lime in the connate water from that in the present mine waters except for the curious fact that Ca : Cl does not go much above 0.49.

With regard to the iron and magnesia dissolved at this stage, the iron may have been partly precipitated and may have partly remained in solution as ferrous chloride, since it is ferrous iron that mainly occurs in olivine and augite. If epidote formed, copper might form also, as I have elsewhere shown.

But the magnesium according to T. S. Hunt's reactions[4] would in the presence of calcium carbonate and silicate be thoroughly reprecipitated as hydrous magnesium and ferrous, more or less

[1]Treatise on Metamorphism, p. 388.
[2]Loc. cit., p. 378.
[3]Apatite is not recognized in the lavas generally.
[4]Chemical and geological essays, pp. 122, 138.

aluminous silicate. This is so characteristic of melaphyres that green earth (chlorite, diabantite, delessite) has been taken to be an essential constituent. The mine waters, though nearly free from magnesium, may once have contained more in proportion.

The absence of Mg in the mine waters and its tendency to replace all other minerals, even porphyrite pebbles, is one of the well settled factors in the problem. The ratio of calcium to chlorine in the waters may originally have been more or less than that now, since calcium has been taken up from the augite and thrown down again in epidote, etc., except that in the deeper waters it is closely dependent on the ratio of sodium to chlorine and in the waters of the deep mines the ratio of sodium to chlorine was probably about the same since there are no secondary minerals in which sodium or chlorine have been precipitated and little or no sign of any change by which chlorine could be leached. The present ratio must be greater, if anything. So far as hydration has gone on the concentration is likely to have increased unless affected by circulation of fresh water taken in at the outcrop.

The native copper specks found isolated in doleritic streaks or in the center of a heavy trap bed[1] may be accounted for by this primary local decomposition.

But to have valuable accumulation of copper there must be not merely the decomposition of the rock and the concentration of the copper near by but a considerable migration, since the rocks on the average run only something like 0.02% of copper. Unless, therefore, there was a migration of the water it could only take a little from the rocks or add a little to them until equilibrium was established.

It is probably true that in nature the chlorine waters act not merely locally but on a large scale, that there is not only a migration of ions as in a battery fluid but a migration of the fluids which tend to sort and collect the different ingredients, the arrangement being similar laterally and vertically, but differing somewhat according to the temperature and pressure in exact composition. For instance, epidote might be formed in depth where in the presence of a water of corresponding concentration near the surface the oxidation of the iron oxide would lead directly to hematite and red clays. Nearer the surface too there might be more CO_2 and the lime go into carbonates.

Thus surface alterations laterally from the main channel of porosity and the downward succession might be not exactly the same and yet have points of resemblance.

[1]e. g. Tecumseh at 164 feet (Box 16).

In Franklin Junior Holes 3 and 4 the various zones are well developed, the highly altered red amygdaloid with calcite amygdules, often brecciated, grading down into hard grey or yellowish green, with quartz and epidote. The feldspathic trap underneath toward the base becomes darker and more chloritic. Clark Bed 13 illustrates the occurrence of copper adjacent to the pervious bed proper. Again in Adventure d 5 at 710 feet the last two inches of the trap just above the conglomerate is heavily charged with copper, and the Nonesuch-shales carry copper for some distance above the pervious underlying sandstone which is the lode proper. A shattered zone characterized by irregularity in comparing different sections is just the place along the margins of which copper seems to accumulate, e. g. the Baltic, the Calumet conglomerate and two beds below, the Osceola, the horizon of the Montreal lode, the Pewabic lode.

CONCENTRATION AND MIGRATION.

Cooling after the first stage of immediate reactions must still have gone on and the water enclosed must have shrunk, and *if the rocks had already been so much cemented, that as they cooled they no longer settled so as to squeeze the water out*, then—since for water the cubical expansion and contraction by change of temperature is greater than for rocks[1]—there would have been a tendency to contract within the rock and draw in fresh water at the outcrop.

A drop in temperature of water from 100° C. (212° F.) to 28° C (82° F.) would mean a shrinking of volume of something like 4 percent while the contraction of rock for the same change would probably be less than 0.4 percent.

If now we assume some porous bed of the Lake Superior basin extending from Keweenaw Point to Isle Royale (say the Allouez conglomerate) to have a length of 60 miles across and the water therein to have contracted equally from both sides as it cooled then the early waters might have shrunk (.04 x 30 x 5280) about 6300 feet on each side. This would not be equal of course all along the outcrop. The relatively fresh water sucked in by this shrinkage would penetrate farther where topographic conditions and greater porosity favored it and then spread laterally. If any part of the formation was filled when buried not with water but with gas the

[1]Which is natural as the amount of heat given off in lowering a given volume 1 degree in temperature is about twice as much. Data are given in the Chemiker Kalender.

shrinkage in cooling and condensation would be very much greater.[1]

Thus so far as the amygdaloids were buried with the bubbles filled with gas only, and occasional bubbles occur scattered all through quite massive beds of trap, there are tremendous possibilities of absorption. The regularity of this shrinkage and absorption circulation must have been interfered with in various ways. Let us enumerate some of the factors, each of which will be effective only so far as other factors do not interfere.

1. It must have been more extensive in the most porous and pervious beds.

2. But slide faults, seams or slips or pinches or anything that tends to check the continuity of the pervious beds might have checked this circulation.

Some examples are the following. The Central mine vein was good down to the Kearsarge conglomerate, and was stoped up on it. It was barren below. (Figs. 30 to 33) The Victoria mine found barren rock below a fissure which dipped about 45° to S. 10° E. and cut the shaft at the 14th level plat and the 14th level about 200 feet west, dropping the hanging ten feet (Fig. 60). The Nonesuch lode is rich on the upthrow side of a fissure only. The mining men generally report the character of the rock likely to change in crossing a fissure.

There seems to be one factor worthy of special mention. When a bed thickens away from the outcrop, and has but relatively small or thin porous areas at which it reaches the surface the tendency to suction of the upper waters along them will be exceptionally strong if the connections to the surface are kept open.

We have then as our second stage the imbibition of the cooler waters from the surface *which may average several thousand feet* and may be more or less than this according to circumstances. This process must have been very slow as we know from hot springs that heat lingers around such enormous masses of volcanic materials for ages.

Now the coarseness of the crystallization accompanying much of the copper formation points to the action which formed it having been very slow. The large crystals of calcite with copper in them and of copper itself (for instance, the two and one-half inch crystal of copper which Dr. Hubbard has from the Ojibway) are illustrations. Mr. J. B. Cooper tells me that a tooled surface of one of

---

[1]From 200 degrees to 100 degrees for instance it would be something like $\frac{100+273}{200+273} = .71$, something like 30 percent. of its volume. To this must be added its condensation or absorption.

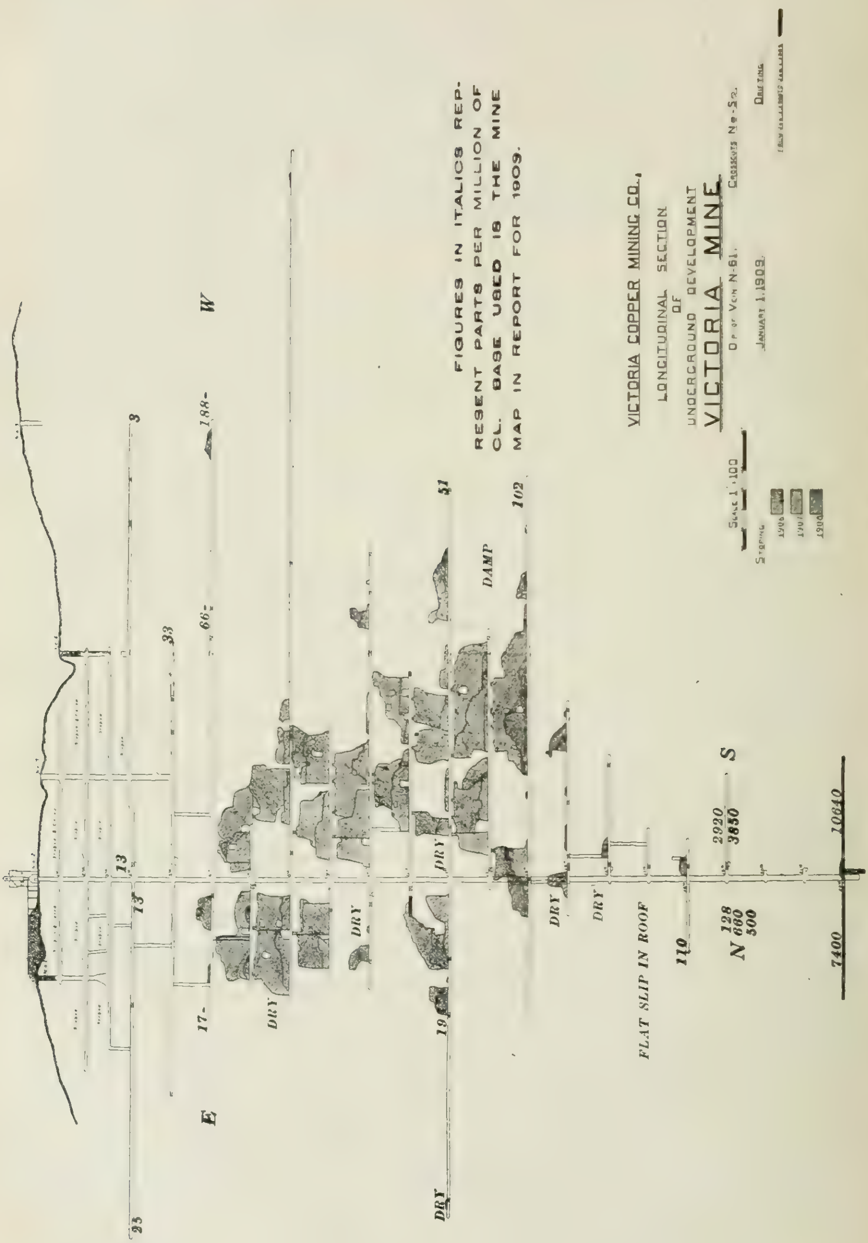

Fig. 60. Geological cross-section of Victoria mine with concentration of mine waters thereon.

the large masses of copper shows the coarse crystallization beautifully, that W. J. Uren once had a surface twenty by thirty inches tooled, and it showed a finer crystallization toward the margin, coarser at the center. This coarse crystallization gives native copper a peculiar density, toughness and hardness to which may be due the notion that the Indians who fashioned instruments of it had some way of tempering copper,—a notion in which Mr. J. T. Reeder, who has a very fine collection of such implements, takes no stock.

One reason why electrolytic copper is not so strong as Lake is that it is usually rapidly formed in minute crystals. If formed in a week it is fine, short and can not be rolled. Were a month used it could be and a year might give the toughness of Lake.[1]

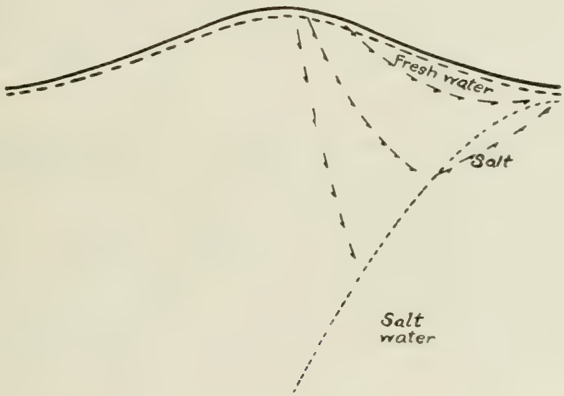

Fig. 61. Theoretical circulation of water from beneath high ground.

And this second stage brings an alteration by descending waters, either (a) the original connate chlorine waters migrating nearer the center of the basin, or (b) the same more or less mixed with waters drawn in from the surface. The pressure will increase. The temperature will increase decidedly when they travel in much faster than the formation is cooling and as underground temperatures always increase slightly, will increase anyway somewhat. Moreover, we must remember that these upper waters will be pulled in in streaks and sandwiched between quarry moisture of the deeper type in the less porous layers, so that we shall have a tendency to lateral reaction and ionic migration between the cooler upper waters in the porous beds, and the hotter, less pervious traps. The tendency for the lode water to be somewhat fresher

[1] J. B. C.

than the country rock water (shown by the analyses) is, if not an effect of mine operations, one of the strongest arguments for this theory.

Thus along every pervious channel on its foot and hanging will be contact zones of the upper water against the lower water, and this is precisely what we really find.[1]

This slow secular sucking of water on a larger scale may take the place of Fernekes' repeated action of the same sort described above.

In the Keweenawan *igneous* rocks we make out two stages of decomposition as follows:

I. 1. Primary reactions, glass decomposes, chloritic filling to cavities, ferric minerals (olivine, etc.) attacked. Chalcedony, agate, quartz, delessite and serpentine, and epidote formed; laumontite, thomsonite and chlorastrolite in amygdules?, iron bearing red calcite, orthoclase? and ankerite?. Some of these reactions may not be all primary.

II. Secondary reactions.

2. Prehnite, other kinds of chlorite, also epidote and quartz formed; lime bearing minerals dominant.

3. Iceland spar (calcite) and copper formed.

4. Selenite, barite, datolite, orthoclase, natrolite, apophyllite, analcite, and the sodium bearing minerals, fluccan.

In the four groups above it must not be understood that the order is absolute but that on the whole the copper is most intimately associated with calcite, but at times occurs sprinkled through the prehnite and epidote as the contemporary.

It is, however, true that the minerals of the last group are rarely if ever formed before those of the earlier ones and the first group are often replaced by the later ones. Chloritic replacements are common.

It is understood of course that primary orthoclase of the original felsites may be and often is replaced by the others, and calcite occurs of all ages. An older calcite is often bright red.

These studies are adapted from Pumpelly's thorough studies of the order of crystallization, Volume I, Part II, p. 32 of these reports, with additions.

---

[1]The Osceola lode, an amygdaloid, has always a little copper at the top, then perhaps 30 feet off in the foot again copper, more massive and more irregular.

Early. Late.

Laumontite

Quartz

Delessite and chlorite

Epidote

Prehnite

Calcite

red white colorless

Copper

Silver

Datolite

Analcite

Orthoclase

Apophyllite

Among other minerals whose occurrence is interesting we may note that *powellite* occurred not only in the 14th level of No. 8 shaft South Hecla[1] but in a vein of calcite in the Calumet and Hecla conglomerate five feet from the foot, in the 40th level between Shafts 6 and 7. It came in nests in the calcite in the boulders as well as the matrix. It has been noted also in the rock hoisted from the Tamarack mine with epidote and copper, and President McNair has picked up one crystal of different habit that presumably came from the re-opened Isle Royale, though prolonged search has yielded no more. It seems thus to be,—as one might expect since it is a calcium tungstate and molybdate Ca (MoW) O_4,—a mineral of the calcium chloride zone. Pumpelly noticed that the secondary sodium minerals were confined to the upper levels, those in which the mine waters are also high in sodium. As farther illustrations may be noted the following occurrences.

Analcite occurs in first vein under the drift in Tamarack 5, and at the surface on Isle Royale, in Osceola 15th level, copper older than analcite, later than natrolite, in Centennial, natrolite, coarse square prisms with copper moulded about it.

Salt crystals (J. Pollard) were found on the 9th level of South Hecla and were quite likely due to evaporation and the product of mining operations. They are interesting, though, as the shallowest indication of salt water at the Calumet that I have.

Capt. J. Chynoweth presented the Survey with a fine specimen

[1]Koenig and Hubbard, "Über Powellit, von einem neuen Fundorte." Palache, C. Am. Jour. Sci., (1899) VII, p. 367.

of polished quartz, copper, silver and calcite from the Old Colony lode, showing their mutual relations.

A convenient place to see the minerals is the dumps of the Isle Royale Consolidated mine (Pl. XI), not only near the mine but on a siding of the track to the mill. A fine collection will be found in the College of Mines, largely due to the collecting of Professor Seaman and his students. Here have been found:

- Primary
  - Labradorite
  - Augite, (the ophitic mottles show well at the Mabb vein dumps).
  - Magnetite
    - Hematite, also secondary
  - Olivine (? wholly altered to bowlingite, rubellan, Iddingsite, serpentine, chlorite, etc.)
- Secondary early
  - Quartz associated with calcite and copper in crystals at times with 2P2 and trapezohedra as described by Lincio.[1] One piece is dusted over with iron oxide, then laumontite formed on it, then later calcite and last barite.
  - Chalcedony and agate banded
  - Chlorite occasionally in hexagonal light green barrels, well crystallized but universally diffused. There are several minerals included probably.
  - Delessite is the name commonly used for the dark green variety that often lines the amygdules and is early.
  - Saponite is reported
  - Kaolinite
  - Serpentine after olivine
  - Laumontite, reddish, mainly in seams, readily crumbling, sometimes after quartz and before calcite
  - Powellite, one crystal only, found by F. W. McNair.
  - Prehnite is generally in light greenish barrel shaped crystals and radiating fibres like thomsonite. Palache found some yellow at the Phoenix.
  - Epidote, yellow and yellow-green, often in crystals.
  - Calcite is both early and late but largely later than some of the quartz chlorite and epidote.
  - Dolomite seems to occur more in veins.
  - Siderite and the red calcite seems early in formation.

---

[1]Neues Jahrbuch fur Min. B. B. XVIII, p. 155, 156. (−4, −3 74), (−3, −2 53) (−12, −7, 19,12), (−9, −5 14 9) (−15, 8, 23, 15), (−2 −1 32) on No. 1; (7 2, −9 9), (3 1 −4 4), (−11, −8, 19, 12), (8 19 8) on No. 2; (90, −97), (40, −41), (11, 0, −11, 1), (8 1, −9 8), (11, 10, −21, 11) on No. 3.

Ankerite occurs as a vein filling.

Thomsonite occurs in thin radiating fibres on the sides of a seam.

Copper occurs in amygdules and veins, but the copper compounds only in veins or secondary after the copper, and are all much rarer than it, must indeed be hunted for and are hard to find.

In veins are:—

Bornite, rare.

Chalcocite, not so uncommon.

Chalcopyrite. I have seen it in one small speck imbedded in a piece of chalcocite that Seaman has.

Whitneyite

Pyrrhotite? reported

Domeykite

Due to weathering and surface carbonation are

Azurite

Malachite

Chrysocolla

Cuprite. Capt. J. Vivian had a fine specimen showing a core of native copper changing to cuprite and chrysocolla.

Silver with native copper.

Characteristically late are

Limonite

Natrolite

Orthoclase as a secondary mineral

Analcite (also found at Champion mine by Palache)

Later than the calcite are the sulphates such as:

Anhydrite (a calcite vug has a gypsum filling with anhydrite center).

Gypsum, after anhydrite.

Barite, not very uncommon, the last mineral formed so far as I remember.

Datolite is generally the porcelain variety forming the center of nodules of decomposition, often surrounded by a coating of copper. This form often occurs at the Franklin Junior mine also.

Summing up we may say that the later minerals that form mainly after the copper, the zeolites with soda, the sulphates, etc., are the minerals whose bases occur mainly in the upper and middle waters while those minerals which distinctly and always precede the form-

ation of the copper, to-wit, the lime zeolites, are those whose base is characteristic of the lower water and that up to the stage of the copper formation whatever solution of country rock might have been, or reaction therewith by the water and precipitation, they could not have been such as to lower the ratio of sodium but presumably such as to increase it.

Now how do these facts check with the chemical reactions that would be likely? Coming back to the sucking in of surface waters and picking out from the numerous ions existing in the waters only those most necessary to understand the reactions (but not forgetting that the presence of other ions may be necessary in order that these reactions may go on) the middle belt of waters rich in sodium chloride is thus accounted for, and the salt crystals in the Calumet and Hecla and we have

$Na_2CO_3 + Ca\,Cl_2 = 2\,Na\,Cl + Ca\,CO_3$

$CO_2 + O + Ca\,Cl_2 = 2\,Cl + Ca\,CO_3$

As the sodium and chlorine accumulate they tend to find new partners, perhaps in the albitic molecule of the country rock. Thus

$8\,Cl + Na_2\,Al_2\,Si_6\,O_{16} = 2\,Na\,Cl + 2\,Al\,Cl_3 + 6\,Si\,O_2$,

but this would be only a half-way house. Perhaps the real step would be the formation of natrolite, leaving 4 Cl and 2 $Si\,O_4$ ions to wander farther for partners, the fluid being less acid, and the country rock feldspar changed to natrolite.

$2\,NaCl + 2\,Al\,Cl_3 + 2\,SiO_2 + 2\,H_2O = Na_2\,Al_2\,Si_3\,O_{10} + 2\,H_2O + 4\,Cl$

This is merely a theoretical reaction that may go on momentarily in the zones where the natrolite, analcite, orthoclase and apophyllite are formed. By slight changes the same type of reaction may be made to apply to orthoclase and datolite. It is noteworthy that this leaves Cl in the downward working water.

In the presence of salt (sodium chloride) iron tends strongly to rust, and salt and red rocks are everywhere associated with the circulating waters. So with a reaction that produces sodium chloride it is natural to add one that produces ferric oxide if there is any iron chloride in the solution.

$3\,H_2O + 2\,FeCl_3 = Fe_2O_3 + 3\,H\,Cl$

Put the HCl of this reaction in the place of NaCl above and combine the two equations and we have a reaction that will produce the red fluccan clays. It is noteworthy that the secondary orthoclase is generally reddish and brick red orthoclase and analcites are not unknown.

R. T. Chamberlin[1] cites from Precht a reaction a little different

[1]Loc. cit., p. 77.

from this but of especial interest to us as it might account for for the combustible gas actually found in the mines and by Chamberlin in the rock and the reduction of copper, to-wit,

$6\ Fe\ Cl_2 + 3\ H_2O = 2\ Fe_2\ Cl_6 + Fe_2\ O_3 + 3\ H_2$

The hydrogen of this reaction will tend to form HCl with chlorine if the latter is weakly bound, or would be available as a reducing agent for copper.

Now we know that ferric iron is formed, that we have red amygdaloids and we know that the country rock, even the felsite, is attacked and replaced. These reactions above tend to produce an excess of chlorine and therefore just where the oxidation takes place copper will not be deposited, but rather that already deposited will be dissolved and moved down to where the neutralizing agent, the country rock is in excess,—that is, copper will tend to replace this latter. But silver chloride is less soluble than copper chloride and would lag behind, and when moved be deposited on it. It must be remembered that silver chloride is quite perceptibly soluble in strong chloride solutions.

1000 cc. of a 41.26% $Ca\ Cl_2$ solution contains 6.28 grams

1000 cc. of a 25.96% $Na\ Cl_2$ solution contains 0.96 grams

so that it would be soluble in the strong mine waters and tend to precipitate as they were diluted or the calcium base replaced by sodium, that is in the upper waters and as these migrated downward. We see that the distribution of silver and the mine waters match beautifully, for silver is most abundant in the upper levels and the south corner of the Calumet and Hecla shoot (see Pl. VIII) was said to be fairly "lousy" with silver, the percentage of which was 5 up to 54 ounces but decreased to 4¾ ounces per ton in the Tamarack mine. Silver is characteristic of Lake copper, for electrolytic has less silver while the "Western" copper, if it has silver, has also tellurium and bismuth.

The chlorine which dissolves the copper would also attack calcium carbonate if already present. Thus we may account for the migration of copper and calcite at the same time in this way. But we also have to consider variation in the concentration of the salt solutions. Lime is more soluble in a hot calcium chloride solution than in a cold and lime and calcium bicarbonate both have a maximum solubility for a certain percentage of sodium chloride. Of calcium bicarbonate there may exist as much as 0.225 grams per liter if there are 50.62 grams of NaCl also in solution. It would seem possible, therefore, that a simple migration of the middle water zone downward would slowly dissolve and then slowly reprecipitate the copper.

We may thus account for the migration of the copper and calcite and their close association. Such reactions might be written

$2\ CaCO_3 + 4\ Cl = Ca\ O_2\ Cl_2 + CO_2 + Ca\ Cl_2$

$CaCO_3 + CO_2 + H_2O = (H_2\ CO_3 + CaCO_3)$.

$3\ CaO_2\ Cl_2 + 4\ Fe\ Cl_2 = 2\ Fe_2O_3 + 4\ Cl_2 + 3\ Ca\ Cl_2$.

Capt. J. Pollard has a pebble from the Calumet Mine dissolved out so as to leave a vug lined with beautifully crystallized orthoclase and hematite.

This reaction very probably does not take place except in the presence of other ions, but it went on as Fernekes' test with prehnite showed to some extent under those conditions, as red oxides were formed.

If we attack the bicarbonate product above we have:

$(H_2CO_3\ CaCO_3) + 3\ FeCl_2 + 2\ CaCl_2O_2 = FeCO_3 + CaCO_3 + Fe_2O_3 + 2\ CaCl_2 + H_2O + 6\ Cl$

Such reactions may suggest the method of formation of the red calcite and red ankerite, which are as we know relatively early products of alteration, and also show how acid ions are continually shoved ahead to find new affinities.

By such migration presumably the copper pseudomorphs after chlorite, epidote, laumontite and even sometimes quartz are formed,—and in fact *almost any rock*, for great masses of trap and solid pebbles of conglomerate may be changed to copper. The reactions are ones of replacement and equilibrium with a large number of ions. Take the simple one

$CaCO_3 + FeCl_3 + 2\ CuCl + H_2O$.

The products are:

in solution + ions Ca (comes in), Fe, Cu (goes out), H;

— ions CO_3, Cl? OH , FeO_3

Besides this there are at various temperatures and concentrations, various amounts of undissociated salts, and possibilities of ions like OCl and Fe O_3. The general effect of dissolving $CaCO_3$ is to add a strong + ion and a weak negative ion. One way to keep balance in the solution is to eliminate some other + ions, which may be and is accomplished by precipitating the copper, and also by converting the + ions Fe into negative FeO_3. If it were not for the possibility of using the O of the — ions CO_3 and OH in converting the + ions Fe into a — ion Fe O_3 which is the kind of change needed to restore equilibrium, the copper ion might take CO_3 or the O of the OH with it. This is what presumably happened in the Allouez conglomerate at the Allouez mine where cores of native copper are surrounded with oxides and

carbonates of copper and chrysocolla for quite a depth.[1] This is exceptional, however. The zone of carbonates is extremely shallow generally and native copper often occurs "at the grass roots".

The same principles apply if for CO_3 we write SiO_3[2], and so the attack on prehnite

$H_2Ca_2\ Si_3O_{12} + Ca\ Cl_2 + Fe\ Cl_2 + CuCl + H^2$

will result in a solution of

+ ions Ca, Fe Cu, H, (AlO_3?) (Si?)

— ions SiO_3 (FeO_3?) (AlO_3?) Cl OH

As the Ca comes in the Cu drops out. The reason why the laumontite does not precipitate the copper so readily as the prehnite, (the fact is clear both naturally and artificially) is probably that the latter contains a basic calcium hydrate group, while the laumontite having simply hydration water has less of the stronger bases + ions like Ca and H and more of the — ions (even though weak) like SiO_3 and AlO_3. The formulae are:

Prehnite $H_2Ca_2\ Al_2\ Si_3\ O_{12}$

Laumontite $Ca\ Al_2\ Si_4\ O_{12} + 4\ Aq$

The solutions obtained in dissolving laumontite would be much richer in alumina and silica and in oxygen in proportion to lime. This might tend to favor the direct oxidation of the iron. Red colors are associated with laumontite.

With the very common feldspar (Ab_2An_3) or labradorite the change to prehnite and epidote is very simply written.

$$Ab_2An_3 = 2\ (Na_2O\ Al_2O_3\ Si_6O_{16}) + 3\ (Ca_2\ Al_4\ Si_4\ O_{16} =$$
$$2\ Na_2O\ 6\ CaO\ 8\ Al_2O_3\ 24\ SiO_2$$

add $8\ H_2O + 10\ Ca$ and subtract $2\ Na_2$ and we have prehnite: $8\ H_2O\ 16\ CaO\ 8\ Al_2O_3\ 24\ SiO_2$. So that this would mean simply the replacement of Ca by Na in the mine water, and its concentration.

The formation of the *epidote* is of considerable importance. Its formula is:

Epidote $H\ Ca_2\ (Al\ Fe_{1\ 6}$ to ${}_{2\ 3})\ Si_3O_{12}$

Prehnite $H_2Ca_2\ Al_2\ Si_3O_{12}$

As compared with prehnite the difference is that there is less hydrogen, considerable ferric iron (about 10%). There is no reason why it might not act as a precipitant of the copper just as we know prehnite does, but less readily, as there are fewer + ions.

There are two kinds of epidote, — a pale colored zoisitic kind

---

[1]Cf. also the Algomah mine near the middle of Section 3, T. 50 N., R. 38 W.

[2]Though there is the possibility of the formation of compounds like $SiCl^4$ and $SiFe^4$ which account for the solution of pure quartz, though rarely, with difficulty, and as a last resort. There must be a relatively large amount of cuprous chloride and little silica in solution in order to favor this reaction.

which is formed in the decomposition of the feldspar and a deeper colored epidote[1] which is the commoner variety and no doubt is richer in iron. The epidote is very commonly associated with chlorite in sharp crystals. The chlorite takes in magnesia and ferrous iron, but not willingly or to any great extent lime and ferric iron. Therefore in the hydrous decomposition of the augite, the lime, alumina and ferric iron of the same are precipitated in epidote as the solution gets over loaded with lime. This early epidote is formed before the copper and is very wide spread where there is no copper, and is almost as wide spread if not quite as abundant as the chlorite.[2]

Epidote also, however, occurs replacing the whole mass of the rock. In this case the feldspar and glass of the amygdaloid are also decomposed. If we compare the formula of epidote with that of feldspar we see at once that there will be silica left over in its formation. And if we take the trap as being roughly CaO, MgO $(Na_2O\ FeO)\ (FeAl)_2\ O_3\ 4\ SiO_2$ and suppose it decomposed into chlorite = $(2\,FeSiO_3)$, Al_2O_3, $3\ SiO_2$, $3\ Mg\ (OH)_2$, $Fe\ (OH)_2$ and epidote = $(AlFe)_2O_3$, $3\ SiO_2$, CaO, CaOH we have shown in chapter II that there must also be, as in the Calumet and Hecla pebbles, silica (quartz) SiO_2 and soda Na_2O to be accounted for. We do as a matter of fact find quartz commonly associated with epidote and chlorite, but often later, the sodium silicate being quite soluble, but precipitated by calcium chloride, giving calcium silicate for epidote.

In the lower part of the lava flows, the hanging of the lodes, there is an accumulation of the lime and iron, while at the top, which is the foot of the amygdaloid lodes there is more sodium (feldspar). Nevertheless, generally speaking, the hanging is chloritic, the foot and the amygdaloid itself more epidotic.

The lime and silica are always abundantly present and the more important conditioning factors seem to be the presence of alumina, and the accumulation of oxygen to oxidize the iron.

This might very well go hand in hand with the formation of copper, and indeed it does, if only the physical conditions were such (as in Fernekes' tubes) that the oxygen derived from the decomposition of silicates by chlorides was preferably employed in building epidote or hematite. On the whole, however, epidote is vastly more wide spread than copper, that is in the attack of silicates the oxygen was in most cases provided for change from the

[1]Thallite or pistazite, yellow in thin section, deep yellow-green. Vol. VI, Pt. I, p. 166.
[2]Capt. J. Pollard says that in the Calumet conglomerate the cement was calcitic, the epidote more confined to boulders.

ferrous iron of traps and chlorites to the ferric iron of the red amygdaloids and epidote without reducing the copper.

Of especial importance is the role of the chlorite family for they are so widespread and often replaced by copper. They have had a great many formulae assigned[1] but the essential thing to remember is that they are a hydrous alumomagnesian silicate with the magnesia always largely replaced by ferrous iron.

The chlorite naturally forms first in the hydration of ferrous minerals like olivine and augite. But that is only the beginning of the story. Chlorite is attacked by chlorine and H Cl, and as soon as corrosive chloride solutions reach a delessite, that bears ferrous iron, they will readily attack it. It is not uncommon to find amygdules that look like solid copper but are a fraud. They were coated with delessite and then this has been attacked and replaced by a thin film of copper that coats around the outside of the amygdule as though it were the first formed.

So the early chlorite is very apt to be attacked by the migrating mine waters. But the mineral brought into solution can not remain in solution. Hunt has remarked that magnesium chloride is precipitated by calcium silicate and carbonate quite completely, and there is very little magnesium chloride in the mine water—barely a trace. It seems, therefore, that the magnesium chloride is thrown out again as chlorite as fast as it is brought into solution, but with this difference, that if there is copper chloride present a proportionate amount of ferrous iron remains permanently in the form of ferric iron, either as hematite or epidote, while the copper takes the place of that much of the chlorite.

This may be written (remembering that all the magnesian part of the chlorite and most of ferrous remains chlorite), for the fraction of the chlorite that reduces the copper, and the fraction of the epidote which has ferric iron.

$$3\ H_4Fe_2\ Al_2Si_2O_{11} + 4\ CaCl_2 + 5\ CuCl_2 = H_2\ Ca_4\ Fe_6\ Si_6\ O_{26} + 6\ AlCl_3 + Cu3 + 2CuO + 5\ H_2O.$$

Compare also the reaction of Chapter II, p. 85.

The aluminum chloride shown in this transformation from chlorite to epidote seems to be used in making more chlorite out of relatively not aluminous minerals like augite and olivine.

The latter seems to be the reaction at lower levels, and may be the source of much of the chlorite on veins, joints and fissures.

We have now, it seems to me, reactions enough to account in principle for all the phenomena of the copper lodes, without sup-

[1] See Chapter II.

posing anything unlikely in the course of circulation, the elements previously dissolved, the character of the country rocks or the temperatures, while there is yet very much to be learned with regard to the relative solubility of the ions concerned.

Pumpelly's theories seem to be altogether confirmed except that chlorine rather than sulphuric anhydride was the acid radical.

Since we are laying little or no stress on sulphates or sulphides it may be well to say why and note a few facts that may be raised in opposition. The reason why we do not consider sulphates or sulphides or arsenides of primary importance is that; first, in many of the mines there is very little sulphur associated with the copper, barely a trace.[1] Secondly, there is very little sulphate in the lower mine water, more in proportion in the upper waters. In the Quincy mine, 55th level analysis, for instance, there is 0.110 SO_4 as against 176.027 Cl, less than a thousandth part as much.

Thirdly, these sulphate minerals are few and rare. Those which do occur are, I think, later in formation than the copper. Beside occurrences already noted are the following:

Barite from 36th level, No. 6 Hecla shaft, very rare.

Phoenix Mine (Palache).

Gypsum (selenite) was in fine pieces in the Mass mine. A specimen three inches long and ten wide came in a vein on the 13th level, Shaft E, of Champion mine on the Baltic lode. The order of formation was, chlorite, epidote, calcite in sharp half inch dog-tooth spar crystals and the gypsum last.

Sulphides and arsenides occur but there is no sign of replacement of native copper with sulphides in depth. The contrary, if anything, is true. It is characteristic that the abundant sulphides are basic with excess of copper. Chalcopyrite is rare. Chalcocite is commoner and occurs in the Baltic and Champion mines in long "seams" nearly parallel to the strike, not in "fissures" across the lode. On the other hand the mohawkite occurs in cross-fissures.

Whitneyite Cu_9As[2] occurs on the 3rd level of the Champion as well as in Mohawk.[2] On the whole, however, the sulphides and arsenides are thought to be superficial.

Domeykite Cu_3As (or stibiodomeykite[2] with 1.29 to 0.7856% Sb) Sp. Gr. 7.906 at 21° C occurs like the mohawkite, which is really only a nickeliferous variety, in the Grand Portage vein.

---

[1] In fact it seems as though there were more in the country rock as the percent of S or As increases sometimes in the lower grades of mineral.

[2] Am. Jour. Sci., (1900) X, p. 446 and (1902) XIV, pp. 404-416.

Ledouxite $(Cu\ Ni\ Co)_4$ As may be a eutectic mixture[1] and is found with the Mohawkite.

Algodonite Cu_6 As. Sp. Gr. 8.383 at 21° C.

Mohawkite[2] $(Cu\ Ni\ Co)_3$ As, a nickeliferous domeykite, Sp. Gr. 8.07 at 21° C. carrying about 63-69% copper, 3 to 7% nickel and 0.5 to 3% cobalt occurs in the Mohawk mine on the Kearsarge lode, and at least as far south as the North Kearsarge lode. A speck perhaps was seen in the Central mine section and Rhode Island d 4 at 529 feet.

It occurs in cross-fissures tightly welded to apparently fresh country rock, and H. V. Winchell thinks it is not a segregation.

According to some indications the amygdaloids are leaner, harder and cold grey epidotic near these fissures.

The occurrence of so-called mohawk-whitneyite with more copper, a mixture of whitneyite with a little mohawkite shows the tendency to native copper.

Keweenawite[3] $(Cu\ Ni)_2$ As (39-54% Cu 9.7 to 20% Ni) is pale red and occurs with Mohawkite in the Kearsarge lode.

Some notes largely derived from the testimony of J. B. Cooper on the distribution of the arsenic and sulphur in the molten copper are suggestive.

On the Kearsarge lode Mr. J. B. Cooper's tests indicate that there is more arsenic on the whole steadily to the north. Mohawkite occurs in the Ahmeek and North Kearsarge mine as well as in the Mohawk. The conductivity is 77½ to 81 at the Mohawk, 89-91½ at the Wolverine, 91 at the Kearsarge. In the Calumet Tamarack shoot the arsenic increases going north and down. But the copper from the Osceola amygdaloid lode under (southeast of) the Calumet has but .0006 As (conductivity 101) while the Calumet has .004 (conductivity 99.5). The Tamarack copper conductivity is 92 to 96, the per cent of copper in the rock melted being lower. The more coarsely crystallized copper is naturally the purest, but coarse copper from the Wolverine contained 0.12 to 0.003% As. However, the arsenic in the "matrix" (the country rock) is generally more than in the copper. The Mass and Quincy have an extra low amount of arsenic. In the geologically higher lodes the arsenic is less. If the conductivity is more than 90 the As is less than 0.04. The Calumet No. 2 mineral has 0.015% As relative to

[1]Koenig, G. A., Am. Jour. Sci., (1900) X, pp. 440-446; Richards, J. W. Am. Jour. Sci., (1901) XI, p. 457; Ledoux, Eng., M. J., Apr. 7, 1900.

[2]Koenig, G. A. "On Mohawkite, Stibiodomeykite, Domeykite, Algodonite and some artificial copper-arsenides;" Am. Jour. Sci., (1900) X, p. 439, also L. S. M. I., VII, p. 62, also Koenig and Wright (F. E.). Proc. Am. Ph. Soc., 43 (1903) p. 219.

[3]Am. Jour. Sci., (1902) XIV, p. 410.

the copper contained. Arranged according to conductivity (arsenic) we have

Franklin Junior 100 and Quincy 101 on Pewabic lode.

Atlantic mine (near Ashbed) 100.

Adventure 101, Mass 100, and Michigan 101.

Victoria 93 to 94.5.

Kearsarge 91.

Wolverine 89 to 91½.

Mohawk 77½ to 81.

Isle Royale 50 to 55.

This is close to the Sheldon and Columbia property and Grand Portage vein from which the arsenides were early described. (algodonite, whitneyite, domeykite, etc.).

Copper Range mines, Baltic, Champion, etc., 65 to 45.

Baltic 45 (with 0.19% As).

It seems to me there are two or three factors involved which need disentangling, and I have not the data yet. The geologically younger lodes often have less As or S. But some of it I think comes from the country rock for the mineral sent to the smelter may run from one-tenth to one-third rock and some from arsenides and sulphides of the fissures.

In connection with what I have written, since I have minimized the role of sulphur it is only fair to insert the following interesting letter which suggests the possibility that the native copper was derived from sulphides by reaction with the salt mine water.

Houghton, Mich., U. S. A., May 15, 1909.

Dr. Alfred C. Lane, Lansing, Mich.

My dear Dr. Lane—* * * * In reply to your inquiry regarding the New Zealand mine in which the sulphide ores of a mine abandoned for 40 years were found partly transformed to native copper by the action of the sea, which had broken into the workings, would say that the property in question, on Kawau Island, was known generally as the Kawau Island Copper Mine, and was worked around the middle 60's, and some work, of a rather desultory nature, was done circa 1901 or 1902, in the way of reopening, and it was then that the native copper was found in the bottom of a comparatively shallow shaft, obviously due to transformation of copper sulphides into native copper through reactions caused by chlorides in the sea-water. The ore, according to my understanding, was exclusively or almost exclusively chalcopyrite, and this mine, which is on Kawau Island, Hauraki Gulf, Auckland, N. Z.,

was worked probably more extensively than any other New Zealand copper mine, until the recent efforts at copper mining of the Ferguson and Maoriland companies, but, of course, the scale of operations are small, compared with any of the important mines of this country. * * * *

Very truly,
HORACE J. STEVENS.

While I give these interesting facts for what they are worth, I am unable to see in them any indication that the copper as a whole is derived from deep-seated rising waters, though one might imagine the arsenic and sulphur to be so. The amount of As or S found in the copper generally is so small that it hardly needs any explanation. Such quantities generally occur in rocks. The thing to explain really is that they are so low. But if we adopt the explanation above outlined that copper replaces minerals that tend to keep a chloride solution alkaline in spite of a tendency toward ferric oxide and chlorine, yielding at the same time its oxygen or an equivalent to the iron, I know no reason why S or arsenic should ordinarily be precipitated or sulphates reduced at the same time. On the other hand sulphur and arsenic seem at times to have accumulated so as to be precipitated, and I would not deny that in this case the depositing waters were ascending. Such sulphide veins have never been followed deep or investigated so as to show their relation to the different types of water. It will be noticed that (whether in the decomposition of the Calumet and Hecla boulders or the turning of an ophite into chlorite and epidote, or any other of the reactions we have cited) in all reactions that lead to the deposition of copper there is a tendency to the same accumulation of sodium in the mine waters, which we actually find at the top of the lower waters, and though after the copper formed the sodium accumulation continued to such an extent that sodium minerals like natrolite and analcite formed, yet these are confined to the upper levels and on the whole the formation of the lime zeolites and decomposition of olivine and augite preceded and the formation of soda zeolites and decomposition of feldspar was later than the formation of copper. The following diagram may sum up our results.

Schematic diagram of bedded lode.

Footwall	Pervious lode	Hanging wall
Generally feldspathic. *Ferric zone.* Surface decomposed zone, full of fractures, and of water coming from the surface only a few feet deep. Red colors—amygdaloids, hematite formed. Soda zeolites may be formed. *Ferrous zone.* Copper is formed or accumulated in a zone of equilibrium laterally and downward where the tendency of the copper to be attacked is neutralized by the supply of decomposible silicates, chlorite, prehnite, etc. ferric iron present built into epidote. Early alterations, water absorbed, feldspar and augite and olivine changing into epidote, chlorite, and serpentine. Glass decomposed, partial amygdaloid filling, original CO_2 gives carbonate.	(*a*) *Upper.* Water largely circulating fresh, Na:Cl more than .65 at first; chlorine less than 200 per million. Carbon dioxide from surface forms carbonate. Chlorine increases, sodium both by solution of feldspars and diffusion. Copper dissolved and carried by the chlorine released in the formation of hematite and soda zeolites to be deposited below or in foot and hanging. (*b*) *Middle.* accumulates sodium chloride and copper. When above a certain strength of copper chloride the mine water attacks a ferrous chlorite, precipitates iron in ferric form at one end of an unequally heated solution, copper at the hotter lower, positive, alkaline end. (*c*) *Lower.* Water, almost stagnant, works slowly down and in, as the rocks cooled and hydrated, gets stronger by loss of water absorbed in hydration and gain of soluble solids. The proportion of sodium falls with depth down to Na:Cl=0.08. Chlorine soon measured in percents, maximum 17.6%.	Much like the foot but more chlorite and augite, less epidote and feldspar. Generally more impervious and so the copper more in thin sheets on the chloritic joints at right angles or parallel to lode on columnar joints at right angles to dip.

It will be seen that my studies have led to no radical change in the views as to the origin of copper expressed by me in the annual report for 1903, and by Wadsworth, in the Transactions of the American Institute of Mining Engineers (xxvii p. 669), and by Pumpelly earlier.

Copper should then be looked for not merely along pervious lines but *near* pervious lines,[1] with a strong tendency to appear in hanging and foot and the mineral crest or richest part of a lode will be in the salt water belt, adjacent either to right, left or below where the downward absorption has gone deeply. (Fig. 60.)

[1]Cf. the figure on p. 127 of Marvine's report, Vol. I., Mich. Geol. Sur.

CHAPTER IX.

COMPARISON OF MICHIGAN COPPER DEPOSITS WITH OTHER SIMILAR DEPOSITS.

§ 1. COMPARABLE DEPOSITS.

It is not my purpose to pad this report with an extensive account of other copper deposits, though such comparison of formations is often very instructive. Many of the deposits of copper ores, especially those of chalcopyrite out west are probably or certainly quite different in origin and mode of occurrence. There are, however, two or three deposits which are so similar that a brief comparison seems to be demanded, for the light thereby to be thrown on our own conditions and this is the more the case because two recent writers have given good accounts of them and have discussed their origin. I refer to the "Copper Deposits of the New Jersey Triassic" discussed by J. Volney Lewis[1], and the deposits of Bolivia described by G. Steinmann.[2] The three deposits all agree in certain striking points, as to which they differ also from most of the western deposits: (1) In all of them native copper is a characteristic ore. (2) In all three the associated sedimentaries are characteristically red, (3) in all three there are associated basic rock, (4) in all three there is a lack of well-defined crustified veins, but the copper occurs disseminated or in irregular large masses in the more pervious beds, not, however, by any means confined in any zone of contact igneous metamorphism. (5) In two and probably three there are saline waters. (6) The silver is more abundant in the upper levels. On the other hand the deposits differ in certain marked respects. They are of widely different geologic age and have not the same associated minerals.

It might be well also to mention the fact that in the red rocks of the Permian, or that general time, copper is known to occur both out west and in the famous Mansfield district. Copper and nickel have also been found in small quantities in the old and new red sandstone of Scotland.[3]

---

[1]Economic Geology, Vol. II, No. 3, pp. 242-257. Other papers by Lewis, Weed and Kummel are referred to in this paper, and will be found listed in the bibliographic bulletins of the U. S. Geological Survey. See also Fenner's paper in the Journal of Geology, 1908.

[2]Die Enstehung der Kupfererzlagerstatte von Corocoro und verwandter Vorkommnisse in Bolivia, Festschrift Harry Rosenbusch, pp. 335-368.

[3]Mackie, Wm., Transactions Edinburgh Geol. Soc. 1903 (VIII, Art. XXVII) p. 258.

§ 2. NEW JERSEY.

The copper deposits of New Jersey occur in the Triassic area. This area consists of a series whose most characteristic sediments are red shales, but there are also sandstones and coarse conglomerates, and black argillites and grey and green flags, which may correspond to the Nonesuch group. In general the sediments are so much like those of the Keweenaw, that on this ground early visitors to Lake Superior were inclined to assume that they were of the same age. There are also igneous rocks, both extrusive and intrusive, whose chemical composition is not far from that of the melaphyres of the Keweenaw series. The over flows occurring in various places, but especially west of Newark, Orange, Plainfield, Bound Brook and Paterson, rise in ridges easily recognized and like those of Keweenaw Point. They contain amygdules and zeolites very similar to many of those found in Michigan. The main intrusive sheet is that which forms the great Palisades of the Hudson over against New York City, and probably extends thence south to the neighborhood of Princeton and Trenton. The dips are rather gentle like those of Isle Royale or the end of Keweenaw Point, 10° or 20° to the northwest. Like the Keweenaw district, too, there are great faults each of which displaced the strata many thousand feet, which would correspond to the Keweenaw and Porcupine Mountain faults. Besides these there are numerous smaller faults corresponding to the smaller fissures of Keweenaw Point, and they run mainly north and south or northeast and southwest. These faults have a down throw on the east toward the Atlantic Ocean. The copper has been shown to exist to the extent of 1/40 of 1% in the extrusive trap of First Mountain and 1/50 of 1% in the pyroxene of the intrusive trap.[1] The commonest occurrence of the copper is as chalcopyrite in the traps and as native copper or chalcocite in the sedimentary rocks. Green and blue silicates, and more rarely carbonates, and small quantities of cuprite and azurite occur. According to Lewis the ores occur in four types of association. In two cases with and in two cases without known intrusive trap.

THE ORE DEPOSITS NEAR INTRUSIVE TRAP.

The Rocky Hill (Griggstown) mine. Essential ores, chalcocite and chalcopyrite in fissures and brecciated zones in flinty black hornstone in which are specks, to inch masses, of chlorite. Tourmaline, magnetite, hematite, epidote and feldspar also occur. The color is sometimes bleached near the ore and the thrust-plane parallel to the bedding carries 3 inches to a foot of fluccan.

[1]Cf. the results of the sludge tests of the Clark cross-section on Keweenaw Point.

The Arlington (Schuyler) mine. Eight miles west of New York City. Similar ores in gray arkosic sandstone near intrusive trap sheets and dikes, and in occasional fault breccias of sandstone and trap.

The Flemington mine. Ores again chalcocite and chalcopyrite with similar associated secondary minerals and geologic conditions. Note the dominance of sulphide ores. The few times I have seen chalcopyrite in Michigan has generally been not far from intrusions.

ORE DEPOSITS NEAR EFFUSIVES.

The Somerville (American) mine. Three miles north of Somerville, lying just under the big outflow of First Mountain, the copper mainly in the upper 2½ feet of shale below, and sometimes running up into the hanging for ½ foot. The metal is in grains, strings, sheets, and ragged masses up to over 100 pounds. Beds of native silver also occur. Immediately about the copper and shale is bleached, just as some of the Calumet and Hecla pebbles are bleached probably. It is intimately associated with calcite which seems to have been replaced in some cases by copper. Prehnite and chalcopyrite also occur. Exactly similar conditions which anyone will recognize who is familar with our Michigan deposits, have similarly occurred clear way around to Plainfield.

The Hoffman mine. Two miles northwest of Somerville on top of the trap. Some chalcocite in the sandstone and brecciated trap near the fault.

ORE DEPOSITS APART FROM KNOWN IGNEOUS ROCKS.

The New Brunswick mine. Close to Rutgers College. Sheets of copper have been found in the joints of red shales and small grains disseminated through the rock. No trap is known to occur, or has been struck by wells over 400 feet deep, which are all in the red shales.

Menlo Park Mine. One-half mile north from the station. Native copper in the dark grey shale which is the wall rock and makes up the breccia of a fault. The shales elsewhere have the usual bright red color. There is also some chalcopyrite and magnetite in the shale. Copper in thin sheets and films in the joint cracks like our Michigan leaf copper. There are also minute grains and streaks in the shale, especially around the occasional bituminous plant remains.

Glen Ridge. Four miles northwest of Newark. Grey sandstone with disseminated chalcocite and green with chrysocolla. The minerals especially gather around bituminous plant remains.

Newton. Four miles northeast of New Brunswick. Native silver in scales and particles in the grey sandstone, stained green.

§ 3. ORIGIN OF NEW JERSEY COPPER.

Weed suggested, in 1904, that the ores were due to surface percolating waters, partly changing the trap as follows: The melaphyre chloritized and the iron changed from silicate to ferrous salt.

The calcite amygdules formed in the basalt and pores of the altered shale. The copper was dissolved out from the trap by percolating waters and carried downward. Copper and calcite were deposited in the pores of the ore, the chalcocite being reduced at the same time as the ferric oxide about it. He supposes solutions carrying the copper contained alkaline carbonates and precipitated copper and chalcocite with calcite, and that the reduction of the chalcocite to native copper was due to organic acids. Weed argues that if as Pumpelly suggests for Michigan it were ferrous solutions that caused the reduction we should have ferric oxide associated with the native copper instead of the bleached spots, which we as a matter of fact find.[1] Lewis objects to Weed's hypothesis that the trap rock of First Mountain is not enough altered to account for the underlying ores. Of the 1/40 of 1% of the copper originally contained, ¼ would have to be transferred without loss over a sheet 600 feet thick to give 2½% in 2 feet of underlying shale.

To this objection it may be replied that in the first place it is by no means sure that the analysis represents the amount of copper which may have existed in the original trap moisture, and in the second place it is very unlikely that the underlying shale runs 2¼%, save in exceptional spots.

(2) Lewis' second objection is that ores are found above as well as below the First Mountain trap and above the intrusive traps of Rocky Hill and Arlington, and that the system of circulation which would at the same time deposit ores below their source and above is inconsistent.

I can not see that this is necessarily so, any more than it is impossible for a pebble to be coated with iron ore all around, by diffusion from the interior.

(3) The ore at Arlington besides lying above the trap, is out of all proportion in quantity to sheets of this rock.

(4) The thin tabular crystals of calcite are found in unaltered red shales far from the mine and have not, therefore, been supplied from the trap, though, of course, the calcite and amygdules in the grains in the trap have come from that rock itself.

(5) Organic matter would doubtless aid to reduce the copper as is shown by some specimens but the prevailing barrenness of the red shales in organic matter is one of the best established facts in geology.

Weed's theory fails to account in any manner for the ore deposits not associated with the traps.

Accordingly Lewis suggests the following hypotheses.

---

[1] We can get round this by assuming ionic migration as in battery fluid or in Stokes' tubes.

Beginning with the ores associated with intrusive traps he suggests that heated copper bearing solutions and possible vapors arose from great underlying masses of intrusive along the dikes and deposited their chalcocite in the immediate neighborhood while still heated. The chief effect then would be ascribed to the solutions coming directly from the magma. The relatively impervious shales overlying the Rocky Hill instrusive retarded the escape of these waters to the surface. Dikes and accompanying fissures were confined to the immediate neighborhood of the sill in this locality. And he also thinks likely that reaction of the solutions with calcite of the shale contributed to the origin of the shale. As to the origin of the ores, apart from intrusives, he refers to Stokes' experiment where a solution of cuprous sulphate saturated will deposit metallic copper on cooling, and to such acid sulphate solutions he would attribute the deposition of the copper and the leaching out of the ferric coloring matter to the red shales. In other words he attributes all the copper to hot copper bearing solutions, probably magmatic, coming out from the great underlying Palisades trap sill. It will be noticed that he finds the source of the copper in the formation itself and that it is carried in solution, and in these two points we shall agree with him. He does not investigate the extent to which chlorides may have been present nor does he show any definite reason why heat and solutions from effusives might not have produced the remarkable concentration of copper near the effusive trap. We may remark, moreover, that wherever these Triassic traps occur along the Atlantic coast in Connecticut, Massachusetts and clear up to Nova Scotia where they are well developed about the Bay of Funday, where (as at Cape d'Or) there is no sign of intrusives other than the faults and fissures everywhere present we find the same zeolites as in New Jersey and we also find native copper. The occurrence at Cape d'Or which I have examined is strikingly like that of Lake Superior. Here too though the zeolites are different, the lime zeolites are older than the copper or the soda zeolites, which two latter are more nearly coeval. The trap has about 56% SiO_2. It has been described in some detail by Sir Wm. Dawson in his Arcadian Geology. Beside the papers on the New Jersey traps by Darton, Russell, Lewis and Weed, there has recently appeared an excellent description of "Features indicative of Physiographic conditions in New Jersey," by C. N. Fenner.[1]

His account of what I (following Wadsworth) have called clasolitic material, and the amygdaloidal conglomerates is perfectly

[1]Journal of Geology, May-June, 1908, pp. 299-327.

applicable. His conclusions that some of the traps flowed on the land (such for instance, as the smooth coiled ropy topped flows north of Bessemer with their regular pipe amygdule base) while others flowed into lake (some of the inclusion beds and ashbeds) entirely agree with mine. His paragenetic series (p. 315) differs mainly in the absence of epidote, and in his noting chalcopyrite, but not native copper, which, however, as we know occurs.

§ 4. BOLIVIA.

The copper mines of Bolivia lie in more or less of a line running nearly north and south, through the Atacama desert. Of these the one at Corocoro is most fully described by Steinmann,[1] and will suffice for purposes of comparison. The copper occurs in a series of red sandstones, known as the Puca sandstone, very much like the new red sandstone of the New Jersey deposits, but really somewhat younger, belonging to the Cretaceous. Here again the dominant form of the copper is the native metal, and native silver is also associated with it. But sulphides and arsenides like domeykite also occur. The ore occurs in the neighborhood of a large fault and a vertical displacement not less than 350 meters. The copper does not occur at any one particular level in these beds, but in small grains scattered through the sandstone which now and then blend to almost continuous veins running across the formation or sheets in the joints. Especially is this thin sheet and leaf copper liable to occur in the red clays, and sometimes the copper occurs in most fanciful and grotesque forms. In the higher levels (exactly as in Michigan) they used to find silver ore, and beside native silver and copper, chalcocite and domeykite. The ordinary vein minerals are absent. Barite comes occasionally, and celestite, but is very likely primary in these red sandstones. Calcite is even rarer than barite. In this respect there is a striking contrast with the Michigan district. When it does occur it is intergrown with copper as in Michigan. On the other hand gypsum (which is rare, or at least not very abundant in Michigan), is said almost never to fail. It often thrusts itself in between the thicker copper pieces and the surrounding sandstones and may envelope the copper completely. Such minerals as secondary quartz and tourmaline seem to fail absolutely.

Associated Igneous Rocks. No igneous rocks are known nearer than about 15 miles from Corocoro. At the same time Steinmann points out that the occurrence of copper ores in the Andes is generally associated with a certain type of rock known as Andes

[1] Rosenbusch, Festschrift, (1906) p. 335.

diorite, and that this occurs about 15 miles north and not far south. And he assumes that it occurs also not far beneath and that from it have come the solutions which have deposited the copper. In this respect then his theory agrees decidedly with that of Lewis for New Jersey.

Origin of the Copper. The three writers who have discussed with the most personal knowledge and intelligence the origin of the copper are perhaps Forbes[1], Sundt[2] and Steinmann[3]. Sundt thinks that the copper was contained in the form of oxide or carbonate originally in the Puca sandstone and that later sulphurous acids and arsenic compounds which came up with the diorite injection beneath reduced the metal, while the sulphuric acid thus formed combined with the carbonate of lime to make gypsum, which all observers agree usually accompanies the native copper. The form of reaction then would be something as follows:

$$CaCO_3 + Cu_2SO_3 = CaSO_4 + CO_2 + Cu_2$$

It may be noted that carbon dioxide gas is very abundant and a serious difficulty in some of the mines, especially the Cobrizos. According to this theory the copper would be "syngenetic," belonging to the formation itself, and yet in the process of alteration by these waters it would naturally suffer concentration and migration and would not belong in the same place in which it was found in the same way that particles of gold would be found in the placer. Mossbach also considered the copper syngenetic but in a stricter sense, in that he thought that the copper sulphate reacted with the carbonate of lime as the sediments were deposited. Sundt, however, decided in favor of the idea that the copper was introduced (epigenetic). He appeals to the following arguments.

The copper in its native form is doubtless younger than the sediments because it fills secondary jointing and other clefts and makes pseudomorphs after aragonite. It coats over pebbles of quartzite and conglomerate, and then penetrates into the interior, (just as the Calumet and Hecla pebbles are altered) along the fault line. It is found on both sides both in the older beds of the sandstone as main veins or "vetas," and in the younger, more clayey beds as branches or "ramos." Also the copper is closely associated with secondary gypsum and barite. Also wherever the copper is present the red sandstones are blanched, as in New Jersey and Michigan. Also the water of the copper bearing beds is strongly

[1]D. Forbes, 1861. Report on the Geology of South America. Part I. Bolivia and Southern Peru (Qu. Jour. Geol. Soc. 17, 1861: 38-48); 1866, Domeykit von Corocoro (Phil. Mag. (4) 32, 135).

[2]L. Sundt, 1892. Estudios geologicos en Corocoro y en la altiplanicie de Bolivia (Bolet. Soc. Nacion. Min. Santiago. 1892. ser. 2a, 4, No. 44, 104-108; No. 45, 131-133; No. 46, 164-167.

[3]Loc. cit.

charged with sulphates and chlorides of the alkalis and alkaline earths. This is a striking point of resemblance of our Keweenaw mine waters, except that we do not have sulphates to an important degree. With this may be associated the fact that with our deposits the sulphates, such as selenite, barite and celestite, are rarities. He also appeals to the presence of copper on both sides of the fault as showing connection between that dislocation and the introduction of copper solutions. He supposes that copper was introduced as follows.

Long after the deposition of the sandstones and clays, either at the time they were folded and faulted, or later, solutions of cuprous or cupric chloride and sulphate were pressed into certain of the strata, more especially the pervious sandstones, in which certain beds proved favorable for the deposition of the copper. He also assumed that carbonate of lime was derived from the shells of sea animals and that the organic products of decomposition of the same reduced the copper and the iron oxide at the same time. Then the carbonate of iron and lime were removed in the waters containing carbon dioxide, while the sandstone was bleached, as it so often is around organic matter, and in place of the original carbonate of lime, copper and gypsum remained.

The main change by Steinmann in this theory, which it will be seen very strongly resembles that of Weed, is entirely analogous to that suggested by Lewis. Steinmann points out that fossils and organic matter are rare in red beds here and elsewhere, while aragonite crystals and small masses of carbonate of lime and magnesia are found in small quantities of sandstone in many layers. They do not appear to be associated with fossils, but are possibly chemical precipitates. He doubts altogether the introduction of copper as sulphate or chloride, but believes that the oxygen must have been relatively low in the solutions,—in other words that they were either sulphides, sulphites or thiosulphates. Any such solutions would act strongly deoxidizing. (I may remark in passing that I have made some special iodine tests for such salts in our deeper Michigan mine waters, but without showing any trace of them.) Such solutions if not exposed to an oxidizing agent might deposit the copper in the form of sulphides but in the presence of an oxidizing agent, such as ferric oxide and hydrate so abundant in the Puca sandstone, we could have the oxidization of the sulphide at the expense of oxygen of the ferric oxide and the consequent bleaching of the sandstone, which is as a matter of fact observed regularly around every particle, even the smallest. Such bleaching around pyrite is very well known.

Unfortunately, I have not been able to find out as much about South American geology as I could wish, and we have no analyses of the water directly associated with the native copper which occurs there. We do find, however, in Darapsky[1] analyses of waters which suggest at least that similar waters to those found in our copper mines may be the saline waters found in connection with the copper there. For instance, the analysis of Los Banitos is as follows:

Taste: saline
Reaction: neutral
Sp. Gr. 1.0076 at 15° C
Residue dried at 16° C: 9.545 grams per liter
Residue on ignition 8.996
Composed as follows:

$Si\ O_2$	0.273
SO_3	0.150
CO_2	0.086
Cl	4.515
$Al_2O_3 + Fe_2O_3$	0.088
Ca O	0.768
Mg O	0.017
$Na_2\ O$	2.726
K_2O	0.384
Li_2O	0.135
Sum	9.142
Minus oxygen equivalent to chlorine	1.017
Grams per liter	8.125
The sum of the alkaline chlorides is	6.258

This he supposes probably combined in the form of the following salts.

$Si\ O_2$	0.273
$Al_2\ O_3 + Fe_2\ O_3$	0.088
$CO_3\ Ca$	0.196
SO_4Ca	0.254
Cl_2Ca	1.097
Cl_2Mg	0.035
Cl Na	5.144
Cl K	0.732
Cl Li	0.382

[1]Las Aguas Minerales de Chile, Valparaiso, 1890.

The geology of the occurrence is not given but so far as I can judge by comparing with Plate 8, Sec. A of the Atlas of the Physical Geography of the Republic of Chili by A. Pirssis, 1875, it comes from a region in which lavas and red sandstone also occur. Other analyses also are given in this book which contain earthly chlorides, such as Petrohue (p. 108) and San Lorenzo (p. 104). We are, therefore, so far as we at present know, justified in assuming that the native copper formation of Bolivia and Chili may have the same history as that of Michigan, except that calcium sulphate was largely present.

§ 5. OBERSTEIN, GERMANY.

Another district which strikingly resembles the Keweenaw is that around Oberstein in Germany (Lat. 49° 40′ N., Long. 7° W.) where many "Lake Superior" agates are polished. The following factors meet once again.

(1) Tholeyitic, i. e., ophitic traps, as cited by Rosenbusch, Laspeyres[1] and others, of similar chemical composition (see the analyses of the Norheim tunnel rock), containing a small amount of copper.

(2) Red rocks of the time of the Permian and Triassic or "New Red" epoch.

(3) Agates, for the polishing of which Oberstein is famous.

(4) Other zeolites and amygdaloids very much as in the Keweenawan.

(5) Felsites, e. g. those near Kreuznach.

(6) Salt water in depth (?) as suggested by the Durkheim (Lat. 49° 30′, Long. 8° 12′) water cited by Laspeyres[1] which has calcium chloride.

(7) Native copper in depth, carbonates at the surface as C. Otto Hahn informs me.

(8) The Hancock quartz described by Lincio[2] has a peculiar habit in which it resembles a quartz crystal from Oberstein described by Haüy.

§ 6. COMMENTS.

There are some general comments which may be made with regard to the theories here outlined. All of them work with only one solution and assume that its reaction upon solids or its change in physical condition have led to precipitation. None consider the possible mingling or ionic migration in two solutions. It is to my mind a rather serious objection to any theory which attributes the de-

[1] Z. D. G. S., in Vols. XIX and XX, 1868, p. 191.
[2] N. J., B. B. XVIII, p. 155.

position of the copper to rising solutions, which must of necessity be losing heat and pressure that there are no signs, (and this is emphasized by Steinmann especially for Bolivian occurrences), of vein quartz and crustification. From what we know of the solubility of silica in hot and cold water, and from what we know of true fissure veins generally, it would be a fact hard to explain. Copper replaces silica and silica goes into solution. One solution was gaining in solvent power for silica. The occurrence of the salt water as spoken of by Sundt is very suggestive. The occurrence and distribution of these waters is to my mind one of the strongest arguments against the copper having been formed by upward circulation of deeper seated magmatic waters carrying the copper. I can imagine these waters might in the first place not have contained calcium chloride, but how, working upward and cooling, they would form sodium chloride, and then become fresh, I have not been able to understand. A careful examination of the Corocoro mines from this point of view should either relieve the difficulty or make it greater. There is another difficulty which on the ground might perhaps disappear. The veins or bedded lodes in which the copper occurs dip away from the fault, and if the water that deposited the copper came up this fault, it must have gone down backwards and sideways like the splash of a fountain. This seems strange but is conceivable, if we imagine the hydrostatic head very low in the adjacent strata. It must be remembered too that the igneous intrusions at Corocoro, at some of the New Jersey locations and at many of those in Michigan must be hypothetically put in to fill the demands of the theory that the copper comes from them. This does not really add to the strength of it. We also lack in the theory outlined by Lewis and by Steinmann anything which shows why such similar deposits so different from others occur in such similar relations. I would not say, however, that the three deposits were all formed in the same way. It might be falling into a very common and easy mistake to make that assumption, for indeed there are points of striking difference.

The regular association of gypsum with the copper in Bolivia and not in Michigan is one. This may well be accounted for by assuming that in one case a water containing a good deal more of sulphate or sulphide was involved which was lacking in the other. But why should it be in one and not in the other? One answer to this might be that in one case there were sulphides derived from intrusions and the other not, and it is true that even in Michigan, where we find intrusions, we are more liable to find sulphides, such as chal-

copyrite, pyrite and chalcocite. It may also be suggested that the one set of deposits are very old and others very young, and there had probably been an accumulation of sulphates in the ocean which at the early time of the Keweenaw formation may have been nearly free from sulphates. This would, however, be a mere suggestion, because the question also arises whether these red rocks in all three cases do not indicate terrestrial, perhaps desert conditions, and whether in such cases there might not be an accumulation of minute quantities of copper chloride such as are found in the exhalations of Santorin and Stromboli[1], which under proper conditions might work down and be precipitated, according to the reactions suggested by Steinmann, or those which seem to be more applicable to the Keweenaw formation.

This question as to whether certain deposits are syngenetic or epigenetic is not a matter of mere scientific curiosity. If the copper is introduced along certain fissures, then search should be made along these fissures for the porous beds impregnated with it. The vein of the Central mine, for instance, seemed to enrich the various amygdaloids through which it passed. If, on the other hand, the copper was in some sense or other syngenetic, that is to say (I wish to use the term in a broad sense) in the water which came out with eruptions of a certain date, or in the rocks thereof, then it is along such lines that one should look for a continuation of copper bearing lodes.

The wise man will not decide too hastily or lay down too arbitrary a rule, but if anyone will look at Lewis' map of the New Jersey Triassic it will be pretty clear that the base and top of First Mountain are definite stratigraphic lines along which search for copper has proven relatively promising, just as it has along the Kearsarge lode of Keweenaw Point.

It seems to me that in all cases where native copper is the dominant ore it may be well to see how far its accumulation can be explained as a replacement of some substance which going into solution keeps the solution neutral or alkaline, while the acid element (O or Cl) with which it was combined is used either in oxidizing iron or in attack on other elements and perhaps at the other end or pole of the perhaps unequally heated solution. The repeated occurrence of traps, salt water, and red rocks associated with native copper would seem to be more than accidental, and to favor a theory of lateral secretion, using the term in a broad way, so as not to exclude intra-formational circulation.

[1]Lincoln, Economic Geology 1907, p. 260 (II, No. 3, April-May) cited from Janssen.

In coming to this conclusion I do not wish to have it taken too broadly,—it applies to the Lake Superior native copper deposits primarily with some probable application to similar native copper deposits elsewhere. The universal distribution of the copper in the Keweenaw must not be overlooked. The Clark-Montreal figures are elsewhere given. Hole No. 1 at Mamainse gave in 530 feet an average of .0146%. Another feature is the fact that copper occurs at times with no other lode minerals, in the Nonesuch sandstone, for instance.

CHAPTER X.

THE DEVELOPMENT OF THE COPPER MINES OF LAKE SUPERIOR AND THEIR GEOLOGICAL RELATIONS.

BY A. H. MEUCHE.

A large percentage of the people living in states bordering the Great Lakes have, at one time or the other enjoyed a trip on the palatial steamers plying these waters. Those who have been fortunate enough to have gone along the southern shore of Lake Superior and passed through Portage Lake will probably remember Keweenaw Peninsula by its deep copper mines and the ponderous machinery there in use.

Some probably wonder about the beginning of this district and think about the first discoveries and explorations, but few take the trouble to follow the development of this district and determine how the mines have gradually come to be worked on so grand a scale that it takes from half a million to a million dollars to equip one. In order to explain these facts it is necessary to go into the history of the development of these mines. This report, written largely for that purpose, will quote from articles written at various times by different authors. I defend myself for doing so mainly because these original articles give us the view point of the country at that time and contain prophecies, some of which have been fulfilled, and criticisms, some of which have and are being acted upon now and others which I prefer not to hold as my own. This is especially true of Professor T. Egleston's paper of 1877.

While copper has been found along the north shore and on Isle Royale and some mining has been done there, the only locality where mines are worked to any profit is on Keweenaw Peninsula, and to this I shall confine myself. This peninsula which juts into Lake Superior is about seventy miles long and at its base thirty-five miles wide. The trap or Keweenawan formation is the central ridge. In Keweenaw county it extends to the shores of the lake as far west as Bete Grise on the southeast side and to Gratiot River on the northwest side. Here it takes a more southerly trend than does the shore and departs rapidly from it so that when it reaches the Ontonagon River it lies back about ten miles from the lake, being separated from it by the Western or Freda sandstone. The

eastern limit of the trap is marked by a great fault which can be traced from Bete Grise to some distance past Lake Gogebic. This fault does not follow the strike exactly but cuts across it somewhat irregularly so that while we have a horizontal thickness of almost seven miles in Keweenaw county it does not average more than four between Portage Lake and the Ontonagon River. On the east of the copper bearing traps lies the Eastern Sandstone.

In Keweenaw county, owing to the tilting at an angle with the horizon the range is made up of a series of sharp ridges lying parallel with the outer coast line. These cliffs, rising to a height of from one to two hundred feet, face the southeast with cliffy southern and flat northern faces. After leaving Keweenaw County the ridges disappear, due to the higher dip of the strata, and we have a plateau some six hundred feet above the lake, marking the trap range, and sloping gently to the lake toward the west but abruptly dropping off on the east.

In this plateau there are some noticeable breaks, such as Portage Lake and the Ontonagon River, both of which cut across the trap in deep valeys. As a rule the country is covered by glacial deposits. The average thickness is six or eight feet, but there are some heavy moraines, a notable example being Wheal Kate. At other places the rocks lie bare inviting the scrutiny of any prospector.

There are two distinct methods of the occurrence of copper. In Keweenaw and Ontonagon counties most of the copper has been extracted from veins while in Houghton county it is the amygdaloids and conglomerates that are workable. In Keweenaw county veins run across the strata at nearly right angles to the formation. They are within ten or twelve degrees of being vertical and expand and contract at short intervals. Among the most prominent of the mines worked on these veins were the Cliff, Phoenix, and Central.

An entirely different set of veins is found in Ontonagon County. Here they strike parallel with the formation, but generally dip at a higher angle than the country. Among the mines located upon such veins, we have the Minesota, National, and the Rockland. Veins are principally famous for the masses, all of the above named mines having produced them weighing as much as four or five hundred tons.

The mines in Houghton County are worked on deposits where little mass but a large amount of stamp rock is found. These deposits have proven more persistent and more reliable than those of

either of the other two counties. The beds are really a part and parcel of the country having the same dip and strike. The amygdaloids are merely the upper vesicular portions of the lava flows which, owing to their porosity, have become a depository for the copper or copper solutions. This is also true of the conglomerates. While there are about twenty distinct conglomerates traversing the Point, still there are but two which have yielded enough copper to work. These are the Calumet and Allouez Conglomerates.

The copper mines were worked before the advent of the white men. Just how long before is a question. Mr. Jacob Houghton thinks these ancient miners lived during the stone age of the race and another writer that copper used in brazen images during the bronze age was imported from America.

"The high antiquity of this mining is inferred from these facts: That the trenches and pits were filled even with the surrounding surface, so that their existence was not suspected until many years after the region had been thrown open to active exploration: that upon the piles of rubbish were found growing trees which differ in no degree as to size and character from those of the adjacent forest, and that the nature of the materials with which the pits were filled, such as a fine washed clay enveloping half decayed leaves, and the bones of such quadrupeds as the bear, deer, and caribou, indicated the slow accumulation of years, rather than a deposit resulting from a torrent of water."

Mr. Graham Pope, an early pioneer thinks differently. He says: "To us the explanation is simple enough if we dismiss from our minds the troublesome theory of an ancient race coming from a far distant southern land and spending only the season of navigation here. When the Europeans made their appearance on this continent, they brought with them cooking utensils made of copper, hatchets, knives and axes made of steel, and all kinds of attractive ornaments for the person. The native Indian found it easy to obtain all these things in exchange for the skins of wild animals then so plentiful.

He found them vastly superior to any he could make from copper which he could obtain only in the form of float, or of small pieces broken from the rough edges of masses. He therefore had no longer the need of hidden copper which was obtainable by means of hard labor, always distasteful to him, and so his mining operations were abandoned forever.

Two hundred and fifty years and more had passed after the red man had discontinued his work before the white man took it upon

himself. There was then ample time for these pits and trenches to assume the appearance and condition in which they were found in 1845. There was no sign of any work done in the past other than that which could have been done by our modern Indian."

The Indians in the country had no knowledge of lodes or beds containing copper and it was many years after the country was thrown open before the workings of these ancient miners were discovered. It was then learned that almost every vein or outcrop of any value had pits some as deep as sixty feet, extending into the solid rock. At the bottom of these pits were found cartloads of stone hammers, some of which weighed as much as thirty pounds. Here masses have been discovered which were too large to be removed and the marks upon them show that they contented themselves with heating the mass and pounding off chunks. The method of mining was to heat the rock by building a fire upon it, then suddenly cooling it with water, and pounding with their stone hammers to disintegrate it. There is no indication of melting or smelting. Their efforts were therefore confined to middle sized pieces, neither the large ton masses nor the minute particles in the stamp rock attracting them.

When the knowledge of these ancient workings became known to the explorer he used them to aid him in discovering his much coveted copper lode. In this respect they have been of much use.

The discovery of America brought many people to this shore. Among these were the Jesuit Fathers who labored earnestly to establish the Christian Faith among the Indians. To them the Great Lakes offered an easy path to the interior and they soon had penetrated to the head of Lake Huron. In 1641 two priests landed at the Sault Ste. Marie and from a party of Indians learned of a great lake lying farther, which they declared was larger than any other of the great lakes.

Father Mesnard in 1660 set out from Quebec and pushed his canoe along the shore to the head of Keweenaw Bay. Here he remained through the winter and in the spring accompanied by a single Indian entered Portage Lake. In 1668 Father Marquette and Father Allouez established a permanent mission at the Sault Ste. Marie and formal possession was taken in the name of the King of France.

Two years later two Jesuit Priests explored the entire coast of Lake Superior and published a map of the Lake in Paris in 1672.

These Jesuit Missionaries failed in their attempt to colonize this district and to convert the Indians, for it was two centuries after

they came that this solitary wilderness was disturbed by other than the Indians and some adventurous voyager. They, however, left records of their adventures and discoveries and these have proven of immense value not only to historians but as records of the country. The occurrence of copper was one of the objects which attracted their attention.

The first account of the occurrence of native copper on Lake Superior was published in Paris in 1636. The author says: "There are mines of copper which might be made profitable, if there were inhabitants and workmen who would labor faithfully. That would be done if colonies were established. About eighty or one hundred leagues from the Hurons is a mine of copper, from which Truchement Brusle showed me an ingot on his return from a voyage he made to the neighboring nation."

Father Allouez makes mention of pieces of copper, weighing ten to twenty pounds in possession of the Indians, which they esteemed as domestic gods. He also makes mention of a large mass rising from the water.

The first mining operations were begun by an Englishman, Alexander Henry, who in 1771 formed a company and selected a spot twenty miles from the mouth of the Ontonagon River as the seat of his operations. He was attracted to this spot by the erratic boulder found there. During the winter they drifted into the bluff some forty feet but failing in their search they abandoned the place in the spring. They obtained some copper which probably had been chipped from the boulder.

A second attempt, equally unsuccessful but more encouraging was attempted on the north shore. Here they struck a vein after drifting about thirty feet but it narrowed rapidly and soon disappeared. The work was soon abandoned as his associates refused to advance more money. Henry, who seems to have been a good historian, gives a detailed account of his operations but in closing comments "that the country must be cultivated and peopled before copper can be profitably mined."

It has been suggested and probably with some truth that the present ownership of this district by the United States is due to the reports of these early explorers. While Dr. Franklin was in Paris, during the American Revolution, representing the interests of the colonies he probably became acquainted with the records of the Jesuit Fathers and learned of the existence of copper along the southern shore of Lake Superior. Knowing this, would not his foresight tempt him to draw the boundary line as he did? This

is particularly probable when we notice how the line curves up to take in Isle Royale (Vol. VI. Pt. I page 3).

However this may be, it is certain that the upper peninsula did not appeal strongly to the People of Southern Michigan when it was given to them. Prior to admission to the Union both Michigan and Ohio claimed a strip of land bordering on Lake Erie including what is now the city of Toledo. So great was the dispute that in 1835 when a convention assembled at Detroit to define the boundaries of the new state both sides began to prepare for a conflict.

When the matter came before Congress that body agreed to admit Michigan provided the people would relinquish their claim to this most coveted territory and to mollify their feelings offered them the little known region bordering on Lake Superior. A convention called soon after indignantly refused these conditions but later it was decided to reconsider the matter and reluctantly the state accepted the Upper Peninsula in place of the Lake Erie territory and in January of 1837 Michigan was admitted to the Union.

This ends the preliminary history of the Upper Peninsula. Just two centuries after the first published report of the occurrence of copper we find the country little changed, little known and considered of no value. Hardly, however, had this territory been acquired by Michigan than people began to realize its value and ten years later we find a fairly populous country with mining companies. This change is due in good part to Dr. Douglass Houghton and the Geological survey.

The survey of Michigan was begun in 1818-19 under the Federal Government. In the latter year Gen. Lewis Cass, accompanied by Mr. H. R. Schoolcraft in capacity of geologist, proceeded on a tour of inspection which included the south shore of Lake Superior. In July the party entered the Ontonagon River for the purpose of visiting the celebrated copper rock. Mr. Schoolcraft speaks of finding copper along the banks of the river. Many of the reports of copper that they had heard referred to this river but nothing definite was known and it was for that purpose they were making the trip.

With great difficulty they accomplished the trip but the size of the boulder scarcely met their expectations. Still Mr. Schoolcraft thought it remarkable. He says the mass had evidently been moved some distance as the adhering rock was "serpentine" and foreign to the vicinity.

This mass of copper up to its removal was the largest in the

world. In 1842 it was taken to the mouth of the river by James Paull. (Paull or Ehldreds?). Preparing a truck upon which he hoisted the rock, he succeeded by means of a windlass in drawing it down below the rapids. Here he loaded it on a flat boat thence conveying it to the mouth of the river. It was soon sold to the United States Government and has since been on the grounds of the war department at Washington. Mr. Paull remained at Ontonagon and thus became the first permanent resident of the copper country.

At the time or really just before the time of the deeding of the Upper Peninsula to Michigan, Dr. Douglass Houghton, in 1834, commenced its first systematic and scientific exploration and in his first annual report, published in 1841 presented the results thus far obtained. It was this report that attracted the attention of the world and which a few years later caused the influx of people and capital to Northern Michigan. How well he knew what the future was is shown by his words: "While I am fully satisfied that the mineral district of our state will prove a source of eventual and steadily increasing wealth to our people, I cannot fail to have before me the fear that it may prove the ruin of hundreds of adventurers who will visit it with expectations never to be realized." At the same time, however, the nature of his findings were so different from what had been known anywhere else that many laughed at him and dubbed his work as "back woods mineralogy."

Smarting under the chaff he entered into a contract with the United States Government to execute the linear survey of the northern peninsula in connection with a geological survey according to a system devised by himself. The township lines were run by Mr. Burt or under his supervision while the other subdivisions were made by other deputy surveyors. All rock outcrops were examined and specimens taken and locality noted. Besides this, special information was taken for whatever geological or topographical knowledge that could be gained. The system was fairly organized and field work for one season completed when his brilliant and useful career was terminated by his drowning on the night of October 13, 1845.

"Dr. Houghton was a man of indomitable energy and perseverance, and fervently devoted to the cause of science. Had he lived to complete this great work, he would have erected an enduring monument to perpetuate his name. He died in the discharge of his duty, prematurely for the cause of science, prematurely for his own fame."

The next survey was carried on by the United States Geological Survey. In the spring of 1847, Dr. Chas. T. Jackson was appointed to execute a geological survey of the mineral regions of the Upper Peninsula, but resigned two years later and Messrs. J. W. Foster and J. D. Whitney were appointed to complete it. They made two reports, one on the copper deposits in 1850 and the other on the iron deposits in 1851. The fact that none of the essentials have changed show how carefully this work was done.

In 1869 a joint committee of the two houses of the Legislature made a report on the subject of a geological survey of the state and in urging for a geological survey of the Upper Peninsula said: "In the meanwhile these hardy pioneers have labored and waited until now, with a population of near 35,000, a capital invested in 112 companies, for developing copper, of $16,250,500, upon which has been paid dividends of $5,880,000 and an iron interest which, in the twelfth year of its commercial life, produced one-fifth of all the iron mined in the United States, they have rights, and the state has duties—long neglected duties—toward them, which it were wise to no longer neglect."

Acting upon this report the Legislature brought into existence the present Geological Survey. How little the needs of such a survey were realized is shown by the introduction to the first report in 1873 by Major T. B. Brooks in which he says: "The present survey was inaugurated by act of the Legislature of 1869, which appropriated $8,000 per year for the work one-half of which went to the Upper Peninsula. This amount was again divided equally between the Iron and Copper Regions, which gave $2,000 per year to cover all expenses, including salaries, supplies, instruments, travelling, etc. To the $8,000 aggregate for four years from this source the Geological Board added $1,000 for chemical work, making $9,000 in all received by me from the State for the survey of the Iron Regions. In addition to this sum I have expended about $2,000 of my own means, and have not received any compensation for my services. This small sum would have been inadequate to have accomplished anything worthy of the importance of the work undertaken, had not several corporations and individuals generously come to my relief."

Up to the time of Dr. Houghton's report there was little more than a vast wilderness on the shores of Lake Superior. A mission had existed at Sault Ste. Marie since 1668. There were humble missions at L'Anse and La Pointe. At Fort Williams, on the north shore, there was a trading post, but these few places made up the

entire list of settlements. But a few years later a land office was established at Copper Harbor and in 1844 a company of infantry was posted here and their stockade named Fort Wilkins. These two establishments formed a nucleus for settlement.

This became the first camp in the copper country. It was a safe and convenient harbor. Moreover it was right on the copper range and copper had been found right on its shores. There was very little glacial drift to hinder them and the geological horizon could be readily followed. During the season of 1845 and 1846 the place became a city of white tents and it teemed with life and hope. In 1846, a subland agency was established at the mouth of the Ontonagon River. This river afforded a good harbor and it soon became a lively camp. With these two starting points it is little wonder that the two counties of Keweenaw and Ontonagon should become the places of our first active mines as well as original explorations.

Usually all lands are controlled by the Land Office, but in the case of the Lake Superior District, the War Department had charge of it. To begin with they first decided to lease the land, and permits, as they were called, were issued in Washington. They at first covered nine square miles, but it was soon found that the applications were too numerous and there would be a scarcity of land, so a change was made in the permits reducing their holdings to one square mile. "These permits were authority for taking possession of any lands not otherwise claimed. The holder of the permit was allowed one year for exploration, and three years more to mine, with the privilege of two renewals of three years each, making the whole term of occupancy ten years. The department required returns to be made to the Mineral Agency giving an account of the work performed and the mineral raised, and a payment to the mineral collector at the rate of twenty per cent of the mineral value. The term of the grant, or lease, was presumed to be ample to enable the fortunate holder thereof to realize immense gain—such wealth as would enable him to leave his mine, plant and improvements without regret, free to the next comer. In the days when permits were issued they were much sought for. The holder of one of these pieces of paper considered himself a rich man. So valuable was the whole copper district considered to be that it mattered little where one plastered his permit. People were simply wild—hence after an examination, many a rich location was found to be entirely worthless, was not on the trap range, or was covered fathoms deep below Lake Superior; money was made

by the sale and transfer of these permits, but the last holder had the grim satisfaction often of knowing himself sold."

Afterwards commissions were appointed to appraise the mineral lands and they fixed upon a price of five dollars an acre. Later, however, all lands were sold at the price of one dollar and a quarter an acre. By the laws of Michigan no corporation could hold more than ten thousand acres but a later amendment allows mining and manufacturing companies who use charcoal largely to own fifty thousand acres.

The speculative craze commenced in 1843 when the cession of the land to the United States by the Chippewas was ratified. During the summer of this year a Mr. Raymond made certain locations, three of which he disposed of to the Pittsburg & Boston Mining Company, who began mining the summer of the following year. "The first location made was at Copper Harbor, where the outcrop of a cupriferous vein on what is now called Hays Point, was a conspicuous object, known to the 'voyageurs' as 'the green rock,' and had given a name to that beautiful harbor long before it became the center of the copper excitement. A little work was done here in the autumn of 1844, but on clearing away the ground on the opposite side of the harbor, where Fort Wilkins now stands, numerous boulders of black oxide of copper were found, evidently belonging to a vein near at hand, which was discovered in December, and proved to be a continuation of the one worked on Hays' Point.

Mining was commenced here immediately; two shafts were sunk, about a hundred feet apart, and considerable black oxide of copper taken out, mixed with the silicate. This was very remarkable, as it is thus far the only known instance of a vein containing this as the principal ore, or in any other form other than as an impure mass, mixed with the sulphuret of copper and oxides of iron and manganese, and resulting from the decomposition of the common ore, copper pyrites. This proved, however, unfortunately to be only a rich bunch in the vein of limited extent, and which gave out at the depth of a few feet, although the fissures continued." About thirty or forty tons of oxide were obtained.

Finding that their present location would not pay for further development the company turned its attention to its other properties, among which was the Cliff vein discovered in the summer of 1845. This vein was first discovered on top of the large greenstone bluff. Here it appeared to be but a few inches wide containing native copper and specks of silver. During the succeeding fall a

drift was carried into the greenstone a distance of about one hundred feet, but did not prove encouraging.

About this time it was examined by Dr. Jackson and Mr. Whitney who reported that the surface indications were not favorable but because it seemed to widen out and become richer in depth they advised a thorough examination at the base of the cliff. During the winter the miners discovered a small mass while clearing away the talus at the base. This stimulated their search and soon the vein was traced into the amygdaloid. From this point a drift was carried into the vein when, after having proceeded seventy feet they struck a large mass—"a fortunate circumstance, not only to the company, but to the whole mining interest on Lake Superior. It gave encouragement to those engaged in these pursuits, and induced them to persevere. It also demonstrated the true source from which the loose masses occasionally found on the lake shore had been derived. It demolished the fanciful theory advanced by at least one geologist as to the transport of the Ontonagon mass from Isle Royale, and showed that it was not necessary to resort to icebergs and changes in the relative level of land and water to account satisfactorily for its position." (Foster & Whitney.)

To this mine the Copper Country owes much. It acted, we might say, as the fly wheel which carried the country through the depression of 1847 following the wild speculation, when the country was almost deserted. It became a success from the start and in 1849 paid its first dividend, of $60,000, over half of what had been paid in on its capital. Before this time many people had been looking for sulphurets, thinking that the conglomerates and sandstones were the original source of the copper. After much dearly bought experience the explorers began to realize that in and only in the trap range could they expect to find copper. It did, however, have one bad effect, and that was to completely turn the attention of the miners toward fissure veins. They considered it the one thing needful. This was an easy task owing to the bare escarpments facing the south all along the range. Veins crossing the formation and dividing the cliff would be detected in exposed places or the deep breaks would point out them.

A large number of mines were soon located upon these fissure veins. Among those may be mentioned the Phoenix, Central, Conglomerate, Copper Falls and many others. Many of these paid for themselves but all were started with extravagant ideas of wealth. One of the early reports of the Phoenix very readily illustrates this. "The whole known length of the vein is about eighteen hundred

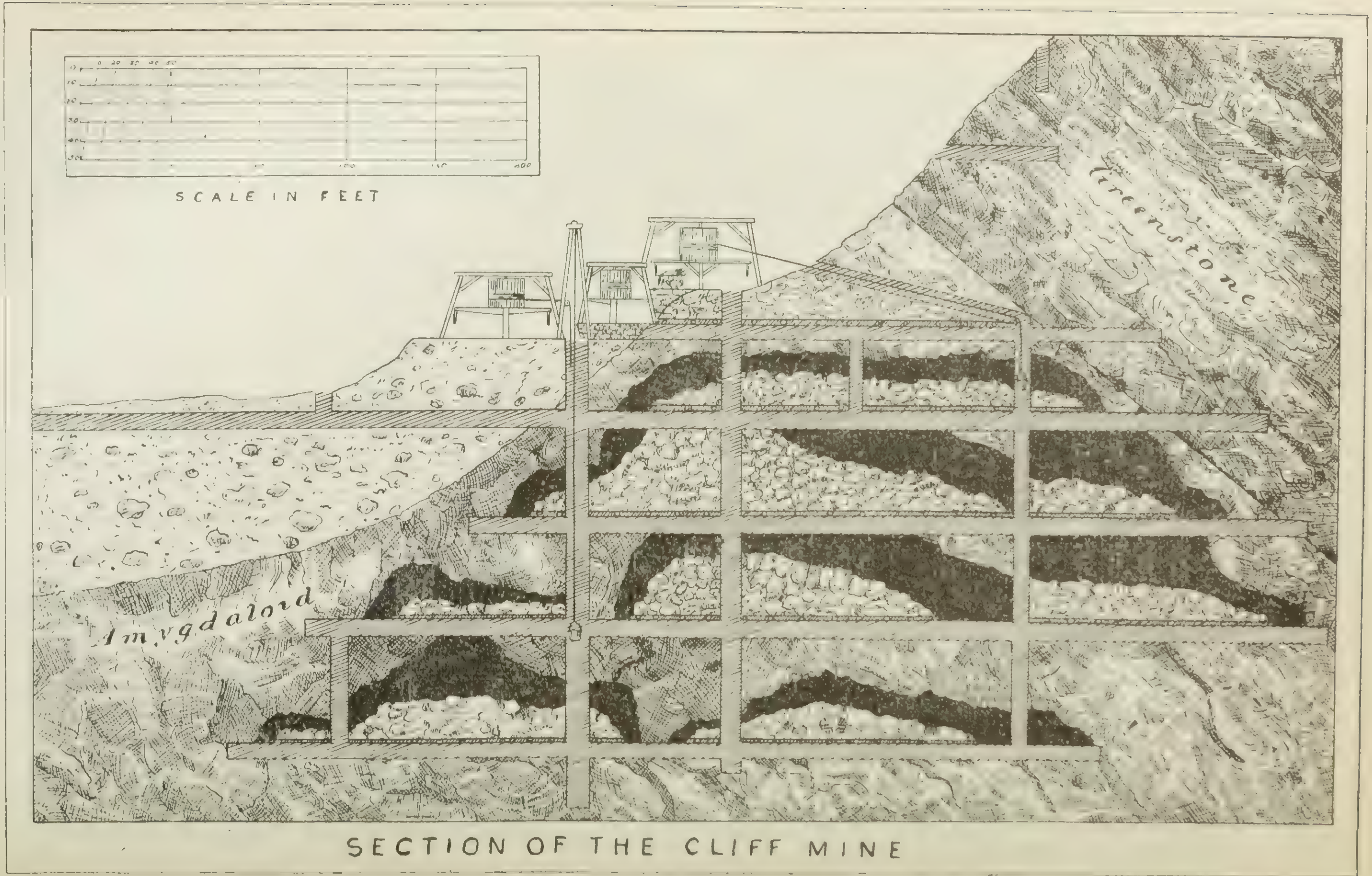

Fig. 62. Cliff mine in 1850. Sketch by A. H. Meuche, after Foster & Whitney.

feet. Its width is satisfactorily proved to be eleven feet for a distance of two hundred feet; and it is probable that it will hold a workable width throughout the eighteen hundred feet. It is obvious that there is an adequate quantity of rich ore in this vein to render the work very profitable, and that there is no danger of exhausting the ore, even should it give out at the depth of one hundred feet, of which there is no probability. If the ore runs out at a considerable depth, say two hundred feet, it will be a matter of little importance to the present generation, though it might be to posterity."

Leaving Keweenaw county with its fissure veins, the next point to be developed was Ontonagon county, where the vein parallel to the formation is the source of copper. Here the first mine of any great value, the Minesota, was discovered by the discovering of the ancient mines. Mr. Samuel O. Knapp, during the winter of 1847-48 observed a continuous depression in the snow, then three feet thick. This snow had been so little disturbed by the wind that it followed closely the contour of the ground. "Following up these indications along the southern escarpment of the hill, where the company's works are now erected, he came to a longitudinal cavern, into which he crept, after having dispossessed several porcupines which had selected it as a place of hibernation. He saw numerous evidence to convince him that this was an artificial excavation, and at a subsequent day with the assistance of two or three men, proceeded to explore it. In clearing out the rubbish they found numerous stone hammers, showing plainly that they were mining implements of a rude race. At the bottom of the excavation they found a vein with ragged projections of copper, which the ancient miners had not detached.

"The following spring he explored some excavations to the west, where one of the shafts of the mine is now sunk. The depression was twenty-six feet deep, filled with clay and a matted mass of mouldering vegetable matter. When he had penetrated to a depth of eighteen feet he came to a mass of native copper, ten feet long, three feet wide, and two feet thick, and weighing over six tons. On digging around it the mass was found to rest on billets of oak, supported by sleepers of the same material. This wood, specimens of which we have preserved, by its long exposure to moisture, is dark colored, and has lost all its consistency. A knife blade may be thrust into it as easily as into a peat bog. The earth was so packed around the copper as to give it a firm support. The ancient miners had evidently raised it about five feet and then abandoned

the work as too laborious. They had taken off every projecting point which was accessible, so that the exposed surface was smooth. Below this the vein was subsequently filled with a sheet of copper five feet thick, and of an indetermined extent vertically and longitudinally." (Foster & Whitney.)

This mine during the early history of the country stood next to the Cliff as a producer. The remarkable results of these two established the reputation of the respective counties and generally the prospectuses of the mining enterprises referred to these as examples, though in fact they were the exceptions. To the Minesota we must give the credit of having produced the largest mass of native copper. Its greatest length was forty-six feet, the greatest breadth eighteen and one-half feet, and its greatest thickness eight and one-half feet, and had a weight of over five hundred tons. This one mass took twenty men over twenty-three months to cut up. The success of the Minesota prompted the miners to locate upon similar deposits with varying degrees of success. Among the more successful stand the National, Ridge and Mass.

These early mines were all mass mines. They cared little for the stamp rock, using crude methods of dressing it, thus obtaining a small percentage of the copper. Owing to the wonderful tenacity of the metal these masses were difficult to handle and required special methods of mining. When one of these masses was encountered a chamber was generally picked out from one side and under it. It was then loosened by levers, but if this proved impossible an excavation was commenced behind the mass, being made large enough to receive from five to thirty kegs of powder. Bags of sand were used to tamp the charge and the drift is barricaded by refuse and loose dirt. The famous Minesota mass required 110 kegs or 2,750 pounds of powder before it was dislodged. First five kegs of powder were used. This was increased until after four futile attempts thirty kegs were used. This shot tore the "immense body from its bed without exhibiting sign of breaking or bending in any place, so great was its thickness and strength. It was torn off from other masses, which still remained in the solid rocks."

These huge masses of copper were too large to be handled and had to be cut up. The copper cutters first marked off the mass into blocks or squares. The tools used were simply narrow chisels and striking hammers. The chisels were made of flat bars of half-inch steel about two inches wide and eighteen inches long. The cutting edge was a little wider than the thickness of the bar so as not to cause the chisel to jam in the cut. A slice was then

taken across the mass of the copper. This slice was flat, about one-eighth inch thick and half the length of the cut, owing to thickening while cutting. In this way a narrow cut was carried through the copper. The contract price was twelve dollars a square foot, at which rate the cutters made about two dollars a day.

These masses were taken to surface and dumped on a pile of logs. When enough masses had accumulated the logs were fired and the whole heated to redness. This disintegrated the adhering rock, which was mainly calcite, so that when cooled it could be knocked off by pounding. They were then marked and shipped to the smelting works where they were melted down in reverberatories.

This early practice of cutting masses by hand is still in use. The greatest difference is that instead of cutting a flat strip they now take out a wedge strip, being thicker on one side than on the other. This arrangement is alternated so that in the next cut the thick side will take the place of the thin one. Instead of heating to disintegrate the rock it is usually pounded off either by a trip hammer or a regular steam hammer.

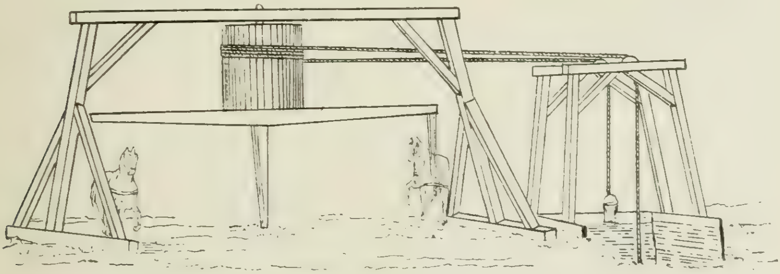

Fig. 63. Horse whim. Sketch by A. H. Meuche, after Foster & Whitney.

The machinery used before 1850 was very crude. Horse whims were then used for hoisting mineral and water. These are best illustrated by the cut in Foster & Whitney's report. The drum at the top held the rope, one end of which was unwinding while the other was being wound up. Thus one bucket, or kibble, ascended while the other descended. Water power could not be relied upon owing to the severe winters which often choked off their supply of power. "In the stamp mills, during the intensely cold weather, it becomes necessary to resort to fires to prevent steam from congealing on the engine, in long icicles, and the ice from forming on the stamp heads." (Foster & Whitney.)

At the stamp mill they had but a few batteries of Cornish Stamps. These consisted of three or four wooden pestles with iron shoes. A cylindrical wooden shaft, with cams, revolving horizontally, successively caught into the shoulders of the pestles and raised them to the required height. They then fell into the oblong cast iron trough which was fed with ore from a hopper above.

These wooden machines were well suited for the country. Wood was cheap, while transportation of better machinery was difficult and expensive. These old Cornish Mills soon became changed as transportation facilities were bettered. The wooden parts were changed to iron and the entire machine being made more adjustable until it assumed the type known as the California type.

The ore mined was divided into three classes: mass, barrel-work and stamp-work. The mass copper consisted of those enormous masses for which the country soon became famous. Masses of less than fifty pounds were dressed by a hammer and barrelled in casks holding from five to eight hundred pounds. This barrel work was estimated at fifty per cent pure copper. Stamp-work included all veinstone with sufficient copper to send to the stamp mills. With the crude arrangements very little copper was saved this way and only the richest pieces of rock were stamped. There was no defined method of washing and only the larger pieces of copper were saved.

The adoption of the skip is characteristic of the change in mining the bedded lodes instead of the vertical fissures. In the fissure mines the vertical shaft was used and the bucket answered very well. The inclined shaft was better adapted for the bedded lodes and even though, at first, they did adopt the bucket it was necessary to slide it along a set of wooden guides at a great waste of power.

Skips were first used at the Ridge mine in Ontonagon County and the report in the Mining Magazine 1856 is of interest. "Their stuff is hauled up on trams laid down the shaft on the inclination of the vein—about 45°—which seems to answer the purpose well. And it is certain that an immense amount of friction is avoided by this plan, if there proves to be no difficulties in its practical operation. Where the vein is so flat it seems to us that its advantages are obvious."

During this period of development the Portage Lake District was lying dormant. It can be seen at a glance that its natural advantages are greater than those of either Ontonagon or Keweenaw

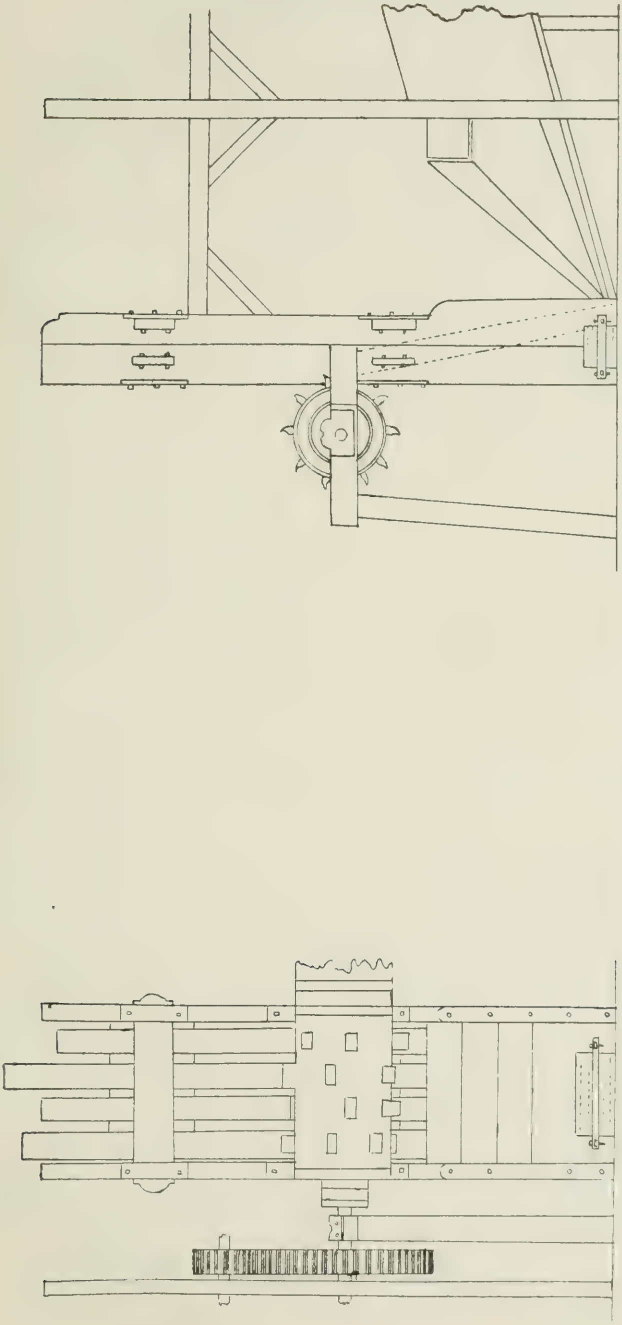

Fig. 64. Cornish Stamp mill. Sketch by A. H. Meuche, after Foster & Whitney.

counties. It lies midway between the two named counties. Portage Lake cuts across the range at the place now occupied by Houghton and Hancock. At Torch Lake some sixteen miles distant from Houghton the shores come within a mile of the range. The shores on the north side of the Lake rise abruptly and at a point half a mile back obtain a height of six hundred feet. Those on the south side are not quite so abrupt, attaining a height of four hundred and fifty feet a distance of one mile from the shore. Mines located near the shore could easily bring their mineral to the shore by means of tramways. There is plenty of water here to run any or all the stamp mills.

There were, however, two great disadvantages to the locality. The first and probably greatest disadvantage to these early miners was the fact that the copper occurred in stamp rock and not as masses. This difficulty has now been more or less overcome at the present time and even though all the copper cannot be extracted, enough can be readily extracted to make the mining of these lodes profitable.

The other disadvantage is in prospecting. The country is rather heavily drift covered so that outcrops are few. These outcrops generally consist of the traps as they are harder and more resisting than the amygdaloids. Hence the copper, which is in the amygdaloidal part of the lava flows, is generally hidden by a layer of detrital matter. This drift, in covering the trap range, hinders the explorer not only in hiding the copper from him but is of much annoyance in other ways. This drift has masses of copper scattered through it and even to this day we hear reports of copper deposits, "just like those of Keweenaw Peninsula," from points as far south as Ohio. It has also been misleading to many explorers right on the trap range. South of Wheal Kate, even into Ontonagon County, the drift is as much as four hundred feet thick. Such a heavy overburden makes diamond drilling very hard and expensive, and even though a promising bed may be located, the cost of sinking a drop shaft may be as much as one thousand dollars a foot thus making the work prohibitory. Hence explorers and mining men are very slow in doing much work in this heavily drift covered section.

During the first few years of the copper country many men came to the Portage Lake District. They came in the early spring and returned to their homes with the approach of winter. The first winter work was in 1846-47 when two parties engaged in mining at two different points. One party drifted an adit under Douglass

Houghton Falls and opened the surface of the rocks at many places in the neighborhood. The work at Wheal Kate was not any more successful although they continued with it until 1853 when the work was permanently closed. Mr. Graham Pope with his dry humor tells of the methods of paying the men at the Wheal Kate Mining Co. "In the absence of a banking system Capt. Pryor paid his men with orders on Capt. Edwards, who in turn, paid them with orders on John Senter, then engaged in business in Eagle River. When a workman wanted money he could easily get it from Mr. Senter after walking twenty-five miles through the forest with his order. Mr. Senter never told these men to come some other day."

In 1848 the Quincy Mining Company started exploratory work on the north side of the lake, but for many years had no satisfactory results. In 1852 the Isle Royale lode was discovered. This was the first amygdaloid lode discovered that contained a workable amount of copper. In 1853 the fame of the Isle Royale lode was spread abroad and many mining companies were started to work it. The Portage lode was found two hundred feet west of the Isle Royale and the Portage Mining Company was organized to work both lodes. During this year the Huron Mining Company was organized with Boston capital to work the southern continuation of the Isle Royale lode. This caused great rejoicing as it was the first large investment of Boston capital here. The first steam boiler in the Portage Lake district was installed at the Isle Royale mine with a horizontal engine of twelve horsepower. When the whistle blew at noon for the first time all men quit work for the day and indulged in a holiday for the occasion.

"In the spring of 1854 the Huron Mining Company decided to use steam power at one shaft and a purchase was made of a locomotive boiler with engine and drum attached. Capt. Bennett made up his mind that that plant should go up the hill by means of its own power. So with an equipment of rollers, blocks, and tackle, with steam up and a lad of fourteen years, C. D. Sheldon, at the throttle, a start was made with Capt. Bennett in charge of the blocks. The people assembled in great numbers to see the work, and voted it better than a circus. During one performance Bennett rushed down the hill at great speed using language carrying a high percentage of profanity. When Sheldon got block and block he found a number of Bennett's fingers on the ground, and then knew what was the matter with Bennett. They got the plant up to the mine, a mile and a half in ten days." (Pope.)

Another amusing experience in regard to the early use of steam power is told by Mr. Graham Pope when they brought in the boilers for the Albion Mining Company in 1854. At that time no canal had been cut at the Portage and the Entry was not navigable for large boats. When these boilers were brought to the Entry no lighters were to be had on which these boilers could be placed. "Finally under the charge of J. B. Lyon, all the openings being plugged the boilers were launched overboard. One of these came back at the steamer and knocked a big hole in her side, but fortunately, above the water line. The boilers were well roped together, the domes being kept upright by means of heavy planks bolted across them. A large sail was hoisted and the boiler catamaran sailed into the river. A large Mackinaw sail boat was then chartered to go ahead with a long cable and the whole outfit sailed up Portage River and Portage Lake fifteen miles to Houghton, where the boilers were pulled ashore by cattle power."

In 1856 the great Pewabic amygdaloid was uncovered by the Pewabic Mining Company organized three years previously. The lode was immediately located by the Quincy Company and from that time forth the advancement of this district has never halted. The Franklin Mining Company was organized in 1857 to work the Pewabic lode and was under the same management as the Pewabic.

These companies decided to build mills during 1858. Both the Pewabic and Franklin mills erected Ball steam stamps. These were the first to be used and they mark an epoch in the history of the copper country. These first stamps were put in under a guarantee to crush twenty-five tons per twenty-four hours. It developed, however, that they were able to do almost twice this much work.

The success of the Pewabic attracted eastern capitalists and the Mesnard, Dorchester, St. Marys, and Albany and Boston Companies were organized to work the lode to the north. The St. Marys and Albany and Boston Companies did not succeed in finding it but opened up the Albany and Boston conglomerate which, while looking good did not prove profitable.

In 1859 the producing mining companies organized the Portage River Improvement Company and dredged out the Entry so that in November, 1860, the steamer Illinois drawing ten and one-half feet of water came to Houghton with 400 tons of freight on board. The work was continued the following year so that it could accommodate any boat able to pass the "Soo" locks which had been completed in 1855. Thus the boats could be loaded at lower lake

ports and brought direct to Portage Lake docks without any portage or use of lighters.

In 1864, Mr. John Mabbs became agent of the Isle Royale mine. To him we are indebted for some of the saving methods which took place. He introduced the large drum for deep winding by installing one of 16 feet diameter at his mine. He induced Mr. Rand who had introduced a heavy drill for tunnelling to make a light and portable one for mine use. With some old engines at the mine he made a compressor and with cast iron pipe conducted his compressed air underground, thus introducing the power drill to the mining world. To him we are also indebted for introducing the diamond drill, having bought an unworkable one in Chicago.

Mr. Mabbs also introduced high explosives, the story of which is told by Mr. Pope. "In 1870, I think it was, but possibly in 1869, Mr. Mabbs bought in New York 4,000 pounds of nitroglycerine oil which was contained in one hundred tin cans. The oil was thirteen times stronger than the black powder then in use. About this time a number of terrible accidents occurred from the use of this oil, and a great outcry rose against it, but after much trouble he persuaded one of the Pennsylvania coal carrying roads to take it. Unfortunately news of its shipment was sent forward when a mob assembled and stopped its passage. It was then sent back one hundred miles, transferred to another road and finally reached Cleveland. Mr. Mabbs, fearing arrest for violating the city ordinances, was anxious enough to get away, but could get no steamboat to take it, and as few sailing vessels were bound for Portage Lake it was only after great trouble he was able to persuade a master to take it to a powder magazine above Hancock. The Hancock authorities, having heard of its presence promptly ordered it out of the place and it was removed to an old stope in the mine. A few days after this, orders came from the east to close the mine, and he had time only for a few blasts. Nothing disheartened he persuaded the Huron mine agent to allow its use there with the understanding that he was to do the blasting. He put up a little magazine back of the burrows and under cover of darkness put there one can only of oil, containing forty pounds. The miners became so excited and furious that they stopped the mine. A great mob gathered and preparations were made to ride the enterprising agent out of the place on a rail, but they did not get him. That night they blew up the magazine thinking all the stock was there. It having leaked out that there was more of it searching parties were formed to get it. It was moved half a dozen times just in

time to save it, and finally it was hidden in the woods just east of where the Mining School now stands. Mr. Mabbs and his brother had in each case handled the oil themselves. They finally loaded it into a yawl boat and started with it for Marquette, which place they reached in safety after a narrow escape from being lost in a storm on the lake. They got permission to try it on some of the hard heads in the iron mines, and were so successful that they had no trouble in closing out their stock and the use of this material was continued there to a limited extent until the present method of making it was adopted, when its use became immediately general." (Pope.)

Early in the fall of 1864 a discovery was made in the woods thirteen miles north of Portage Lake. At that time there were no mines near there and no settlement to induce any search. It was here on Sept. 17, 1864, that Edwin J. Hulbert first located the famous Calumet conglomerate. Hulbert was a surveyor, and during the summer of 1858 he noted a violent deflection of the needle on Section 23, Township 56 North, Range 32 West. This put him on the alert and he carefully noticed signs for mineral discovery. He soon found pieces of conglomerate containing copper but different from any other conglomerate by being brecciated. Later he discovered a big block of it that was covered with moss and a depression which he took to be an ancient pit. With these for aids he after careful and diligent exploration discovered the famous belt. At his suggestion Section 13 was bought and the Calumet Mining Company formed. Later the Hecla Mining Company was formed and Section 23 bought.

One peculiar fact is that the only place where the Calumet conglomerate held a paying amount of copper was bought by Hulbert's advice. Companies were formed to work the extensions of it both to the north and south but were unsuccessful. Another peculiarity is that this conglomerate is the only one that can be considered of value. It is true that the Allouez and Albany and Boston have worked on the Allouez conglomerate but their success is not very noteworthy. The Tamarack is now working the Calumet and Hecla but cannot be considered as working another part of this belt.

As most people know the Calumet and Hecla soon established itself as the largest and richest of any mine in the world. In 1872 it produced 8747 tons of refined copper and during that time paid $2,800,000 in cash dividends. Is it a wonder, when a mine in its seventh year pays dividends greater than its capital, that the

copper country should become famous and draw largely on Eastern capital? As one writer says: "First in the history of the copper country of Lake Superior, fissure veins, charged with enormous masses of metallic copper, had to gain favor; next stamp lodes had to fight their way into popular estimation, and lastly, the conglomerate belts astonished the scientific world."

The year of 1875 can be considered the close of a second epoch in the history of the copper country. During the first period we have the growth of the mines of Keweenaw and Ontonagon Counties. Then the mining industry began to fill in the intervening space forming the Portage Lake district. During our second period we have the growth of this intervening country until it is on a solid footing. In our third period the amygdaloid mines of Houghton County become the chief source of copper while the mines of its neighbors begin their decline. At our present day the amygdaloidal deposits are being found farther north and farther south and following closely upon it are the Portage Lake mining methods. With these changes, Keweenaw and Ontonagon counties once more become the undeveloped regions of the copper country.

By this time the explorer was a man of many accomplishments. He was well versed in woodcraft, knew something of the geology of the country, has studied the working mines and if necessary could do some surveying. Usually his attention was first called to float copper. This float had been torn from the lode and carried along by the glaciers. Upon finding this he would turn in the direction from which the glaciers came attempting to discover if the float became more frequent. If such were the case he kept on until he came to a line beyond which there was no float. At this point he directed his men to trench across the formation or rather at right angles to the strike of the lode. After the lode was found, pits were sunk on the longitudinal course of the lode to sufficiently prove its value. At this time it was believed that lodes which did not show at surface sufficient percentage for regular mining, would not pay farther down. During the last few years, however, this idea has been abandoned. In many mines paying shoots of copper are not found until a depth of a thousand feet or more is reached.

If, however the pits did prove encouraging one or two shafts were sunk to a depth of about one hundred feet. This depth, however, was not fixed, the deciding point being whether the ground were solid enough to allow drifting on the lode. This drift was then run in a horizontal direction along the lode and if two shafts were sunk the one from the other shaft meeting this one connected these

shafts. As these shafts are usually from three to fifteen hundred feet apart a good-sized block of copper ground was thus exposed on four sides and if sufficiently rich a permanent plant for mining operations was erected.

Besides this method of exploring the diamond drill was beginning to come into favor. This helped not only in locating copper deposits when hidden by the drift but when found were of some importance in proving the value of the lode. This proof is used only for deciding whether it will pay to further explore by sinking and drifting on the lode. The Quincy was beginning to use the drill for underground exploration in their mine. Here the copper occurred in scattered paying sheets but which would not pay to work if it were necessary to break down all the rock in order to find them.

The compass and dip needle were and are not as a rule used, though it can be seen by referring to the discovery of the Calumet conglomerate that it is of some use. There is certainly a deflection in the vicinity of the richer copper belts.

In the conglomerate and amygdaloidal mines the shafts were sunk in the copper bearing rock. The number of shafts depended upon the size of the mine and the length of the lode which lies on their property. They varied in size, but 10x14 feet was an average size. They were cribbed from surface to solid rock with square timbers and planks and were divided into two or more compartments. One compartment was used for hoisting, another for a ladder way and a third for pipes and pumps. These shafts were continued down on the lode to any depth which might show copper values in paying quantities.

Levels were laid off from the shafts at convenient distances, ranging from sixty to one hundred and twenty-five feet. These levels were usually six feet high and four feet wide and ran in almost horizontally connecting all the shafts. A slight grade was made rising away from the shaft so that all the water could be conveyed to sumps near the shafts. These mines, however, were not wet and a small pump working but part of the time would take care of all the water.

Between the shafts, for the purpose of ventilation and convenience in stoping, minor shafts or winzes were opened up. Thus a longitudinal map of the main workings of a copper mine could be compared to a map of a city plat, the shafts and drifts being the streets while the winzes would represent the alleys. These solid blocks of veinstone thus laid off were, if the whole lode were work-

able, taken out except for pillars of rock left to support the hanging wall and keep the mines from caving. Heavy shaft pillars had to be left and companies who did remove these were always confronted with a constant and increasing expense.

The method of working was overhand stoping, being done either by hand or by compressed air drills. At this time, however, the air drills were not in great favor as they were very heavy and much time was lost in setting them up and moving them. "No attempt is usually made to fill up the space left by what is taken out of the mine, unless the material is close at hand. In the bed called the 'Ashbed,' at the Copper Falls mine, immense chambers, seventy-five feet square have been left without any support of any kind. The roof is very firm and has stood for many years, but there is no excuse for such methods, for eventually the roof must yield.

There must come a time when wooden props will crush, and then the future of the mine will be compromised, even supposing the shaft or level is kept in order. If a timber be replaced, it must be every time shorter, as the roof descends the surface water is let in, and constant expense of repairs necessary, as witness some of the first levels of the Calumet & Hecla. After a certain time the openings will be either too low to work in, or the roof must be taken out, a hazardous and expensive operation in yielding ground. If the proper pillars had been left, the workings would have remained good for years.

Each company is obliged to own woodland and to select the best of their wood for supports or, as is the case of the Calumet, go long distances, and raft their wood. The method is otherwise bad, as when the ground begins to crack, the superficial waters must come in.

In looking at the vast chambers in many of the mines without any support of any kind, one has an involuntary feeling of dread lest the roof should cave. The solidity of the ground is remarkable, but it must one day give way. The immense amount of rock which has been thrown on the burrows suggests the advisability of filling the old workings of the mine with it and this has sometimes been done in a limited way. If it had been adopted as the policy at the commencement of mining operations, much would have been saved by it." (Eggleston in 1877.)

The rock was picked as much as possible in the mines, the poor rock being left there, and the rest sent to surface. In dumping the rock into the skip, the skip was usually supported upon a beam of wood thrown across the track. Thus the strain of "dumping on

the rope" is eliminated. When filled a signal would be given for hoisting and as soon as the skip reached surface another man would give signals informing the engineer when the skip had approached the dump and when dumped. Some skill was required at this position as any failure on his part might cause the skip to be pulled to the top where it would be caught while the rope was pulled in two.

Skips were made of half inch rolled iron and would hold from one to two tons but these small skips are now used only for exploration work. Many of the present mines use skips holding as much as eight tons of rocks.

The cables which were used for hoisting the skips were of iron or steel. In order to lessen friction and to prevent corroding they were greased with coal tar. "As this substance is always acid from the process of refining the petroleum, this greasing often does more harm than good, as it corrodes the strands and weakens the rope. It would be very easy to saturate the acid, by adding lime and boiling before using as is done in Pennsylvania, but it is not generally done." (Eggleston.)

The drum of the hoisting engine was so arranged by means of marks on it and by a tell-tale dial that the engineer could tell the position of the skip. The velocity was regulated by a strap brake passing around the revolving drum. It was attached to a very long lever of wood upon which the engineer would sit, bearing more or less of his weight.

The present dumping arrangement is the same as was then used. The front wheels were allowed to drop in between the rails while the back ones being wider were carried up the incline. The contents were in this manner dumped onto the grizzlies, the finer pieces falling through while the larger pieces slid into the rock house. These large pieces were usually broken by large sledges but the Calumet and Hecla had installed a steam hammer. This broken rock was then loaded into a tram car and sent to the rock house. One rock house had to answer for a number of shafts, being connected to them by means of an elevated tramway known as the Frue Automatic tramway. The product was then crushed by Blake rock crushers, just as large in size as is in use at present, and stored in bins.

At regular intervals this rock was sent to the stamp mill usually located on the nearest lake. The abundance of water is of great importance. The mass mines were no longer the paying ones and were it not for the fact that the finer particles were readily re-

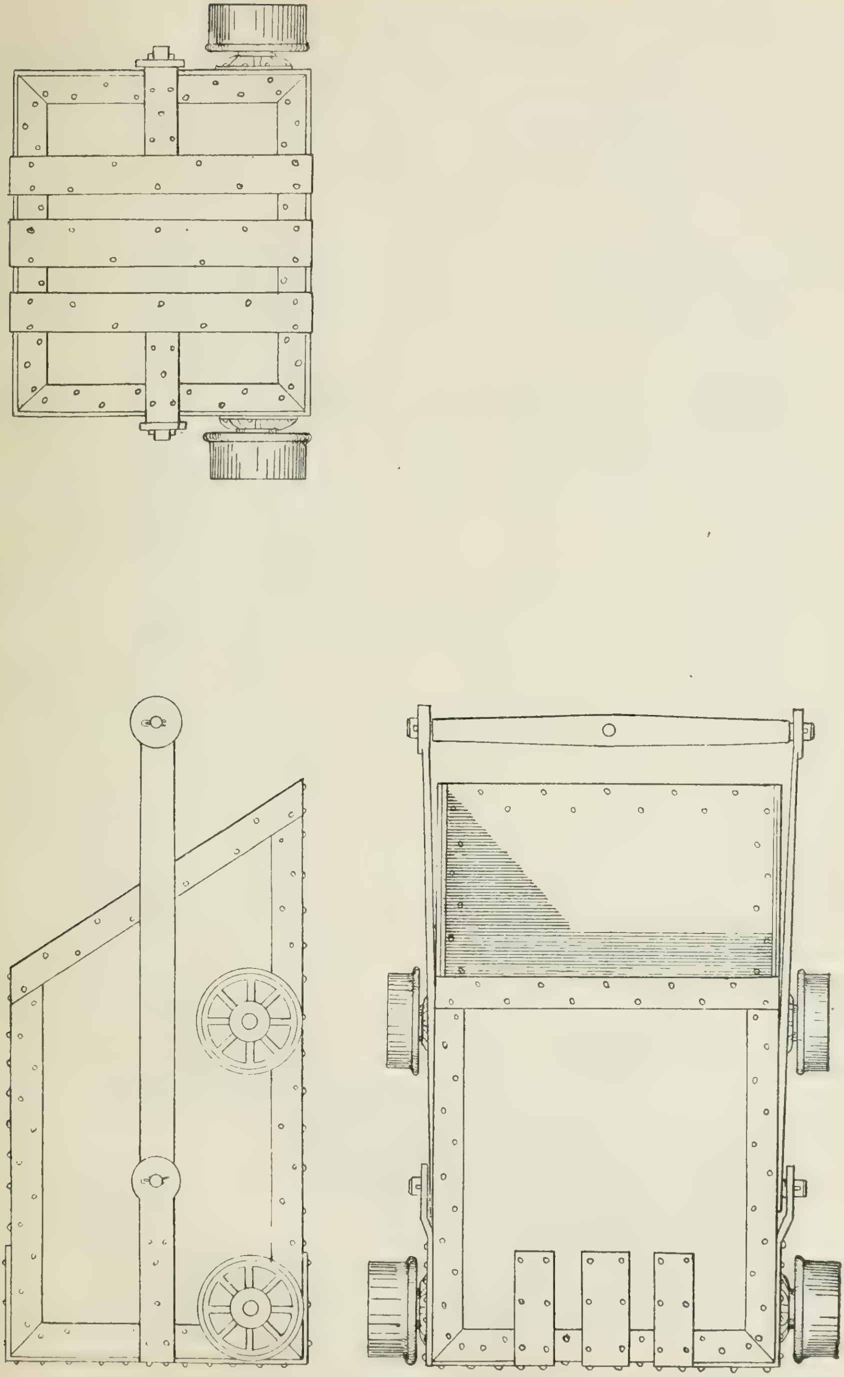

Fig. 65. Atlantic skip.

covered, Keweenaw peninsula would not long have remained a mining region.

At these mills the rock was thrown into the hoppers of the steam stamps. Unlike the present steam stamp these were on spring timbers and a foundation of wood. These stamps were nothing more than steam hammers but the stroke was made regular by having the valves to the steam cylinder operated by an independent engine. This engine was also used to run the washing machines, lathes, etc. A stamp with a twelve inch cylinder making 80 strokes per minute could stamp 120 tons of rock per day with a boiler pressure of 87 pounds.

The next machine to interest us is the Collum Jig. Here the crushed rock is separated from the copper. The crushed rock mixed with a large amount of water spreads itself evenly upon a wire screen, through which a pulsating stream of water flows. The object of the pulsations is to keep the particles in motion thus allowing the heavier particles to settle to the bottom and the lighter ones to collect on top. Those pieces heavy enough to overcome the upward current of water and small enough to pass through the screen fall into a catch box below. The lighter particles are gradually worked off as fresh ore is being constantly added. This machine makes three products; hutch, ore that which falls through the screen, being largely copper, those heavy pieces, mainly copper, that stay on the screen and the tails, which pass over the end of the screen and go to the waste launder.

The slimes which are made by crushing the rock are treated on the Evans Slime tables. This consists of a flat cone having a slope of one in twenty-five, upon which the slimes are deposited. This table revolves and the slimes being deposited upon the table, the water runs down and off the table going to waste. The heavy particles which remain on the table are washed off into a box. These heads are later keeved and a certain percentage of copper removed from them.

In some of the mills the heads, instead of being keeved are treated upon a precussion table. This table was the forerunner of the Wilfley table and operates very similarly.

At this time the tailings from the mill were run to a tail house where the No. 5 copper was recovered. These tail houses hardly paid for their maintenance. While some copper was recovered it took over fifty operations, most of which were manual, to get it. Their main use was to act to some degree as a check on the working of the mills. They were soon abandoned.

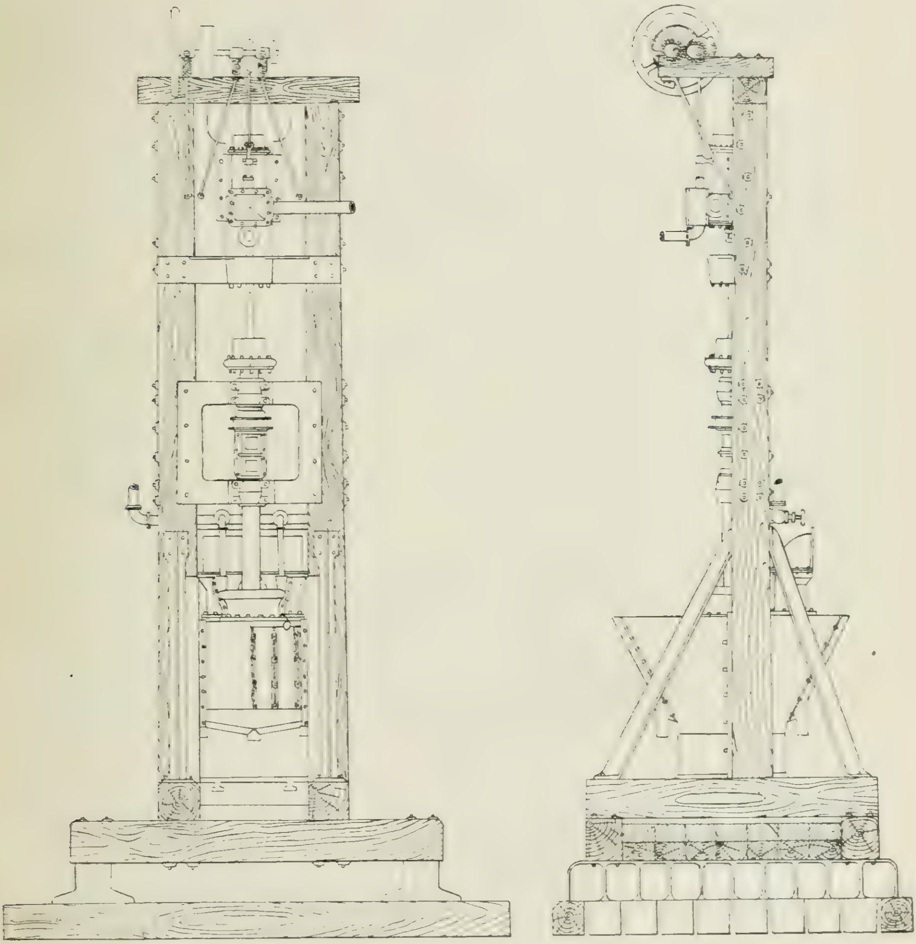

Fig. 66. Ball Stamp of 1875.

"The difficulty of the region does not lie in the want of copper for there is an abundance of it, nor in mining, for, in general it is skillfully done, but in dressing. The following assays of tailings from washers yielding the different grades of copper, I made in the winter of 1875-6. The samples were taken from a mill whose ore yielded less than two per cent.

Tails from Nos. 2 and 3, copper.....	1.325 per cent.
Tails from Nos. 2, 3 and 4 copper....	1.210 "
Tails from Nos. 3 and 4 copper.....	1.030 "
Tails from Nos. 5 copper.............	1.360 "

Much of this copper is attached to small pieces of rock and is carried off with it. This has led to re-stamping the tails, as is done in the Calumet and Hecla; this produces other rich tails, and a large loss in float copper." (Eggleston.)

During this time of gradual development in the mines and stamp mills an equal development was taking place in the smelting of the mineral. The first attempt to smelt copper in the copper country ended in failure. Up to 1850 all the copper was smelted in Boston and Baltimore. The masses were a new proposition to the smelter. All refining furnaces had small side door openings for the charging of the copper ore. At the Baltimore works a large side door was made and masses were dragged into the furnace by chains passing through a door opposite and fastened to a windlass. The result of such a method of charging was serious damage to the furnaces.

The famous "Lake Brand" of copper was originated in 1850. A Mr. Grout together with some brass companies in Waterbury, Conn., organized the Waterbury and Detroit Copper Co. Their object was to get a brand of copper on which they could depend. Before this other brands of copper were not even in quality and equal to their requirements. With this in view the Detroit works were built in 1850 and Mr. James R. Cooper was put in charge.

In 1860 the Portage Lake Smelting works were built in Ripley and they began refining copper in 1861. The Calumet and Hecla sent their product here. In 1867 these works were consolidated with the Detroit works as the Detroit and Lake Superior Copper Company. Thus the position of Lake Copper has been maintained,—not so much to the superior character of the copper but to the purity due to the care in refining.

A few years later than this the various mines erected their own smelters. The initiative was taken by the Calumet and Hecla in

1886. Rolling mills had been erected by 1877 and copper wire and sheets were manufactured in the copper country. This manufacturing has been kept up to some extent ever since.

We might consider that the year of 1894 closes another chapter in this history. At this time all the mines in Ontonagon County were closed and but one mine, the Central, was in operation in Keweenaw County. Copper at this time was selling at ten cents a pound and the country was demoralized. People in Ontonagon County were devoting their time to farming while Keweenaw was practically deserted.

Thus mining was concentrated to Houghton County. The Marquette, Houghton and Ontonagon R. R. had laid an extension from L'Anse to Houghton. Thus the copper country was no longer isolated during the close of navigation. The Mineral Range had connected Calumet with Houghton before this. At the time of writing this article the Copper Range Railroad follows the trap range very closely and runs from Calumet through Lake Linden and Houghton to Mass City where it connects with the Chicago, Milwaukee & St. Paul Railroad. A railroad, the Keweenaw Central, runs from Calumet, along the range to Lac La Belle. Thus Houghton County is connected with both Ontonagon and Keweenaw. Houghton and Hancock are the harbors for the county. All supplies are distributed from here and most all products of the two counties are shipped here. With these two roads as feeders the copper producing district is once more extending into the two counties. This time, however, the mass veins are no longer looked for. The amygdaloidal lodes now attract the attention of the explorers.

Two lodes of great value have been found. These are the Kearsarge and Baltic lodes. While the Kearsarge lode dates back to 1880 it produced in a poor manner and only two mines operated on it. These were the Kearsarge and Wolverine. In 1898 the value of the lode was recognized and it now has more producing mines operating on it than any other. Including prospects there are the Gratiot, Mohawk, Ahmeek, Allouez, North Kearsarge, Wolverine, South Kearsarge, Centennial, Calumet & Hecla, La Salle and Caldwell.

The Baltic lode was first discovered in 1883 and a ninety-foot shaft started on the lode. The lode had a dip of 72° being steeper than any known. This original shaft was sunk on an inclination of 55° and soon ran out of the lode. Disheartened by this, work was dropped and not opened until 1898. With the boom of copper then

on the interest was revived and work was started. Within a short time its value was recognized and many other mines commenced work on it. Among these were the Champion and Tri-Mountain. The Globe south of the Champion has located it but it is 250 feet under the glacial drift. In order to get to it a drop shaft has been started. Up to date this has not been completed. (1906.)

Mining in the copper country is no longer looked upon as a venture but is considered more as a business. Changes have taken place and new factors now enter into mining. There is a constant attempt to cheapen the cost of the product. The cost of production has dropped from fifteen and sixteen cents a pound in 1875 to six and seven cents at the present writing. If a person who has not been in any of these copper mines for the last thirty years, were to go underground in them now he would see great changes and vast improvements. New factors are now to be considered. One no longer thinks of discovering huge masses. The compressed air drill has almost entirely replaced "single" or "double jacking." The drill is no longer so heavy as to cause trouble in removing. Two men can easily handle a drill and a hole can be punched into the rock very rapidly. Lately a hand drill has been devised so that all "block holing" is done by machines. Powder has been replaced by dynamite. Much of this is made in the copper country. Various strengths are used. Thirty-five and forty per cent "powder" is used for stoping, while fifty to sixty-five per cent "powder" is used in drifts, shafts, and for blowing loose small pieces of mass. No large masses are found—two or three tons being the limit.

The next change is in the depth of the mines. A shaft 2,000 feet long is not unusual but a very common occurrence. No. 4 Calumet occupies the position of being the deepest inclined shaft in the world. Measured from its collar to its lowest level it is 8,100 feet. From this level a winze is driven 190 feet farther to the extreme end of the Calumet and Hecla property. They have also sunk one vertical shaft, the Red Jacket, which is down to a depth of 4,920 feet.

At this point the story of the Tamarack will be of interest. They owned land to the west of the Calumet and Hecla. The apex law does not apply to Michigan. In buying land or mineral rights you are entitled to all the mineral directly beneath the surface enclosed by the boundaries set forth in the deed. They realized that on their property were the Allouez conglomerate, the Calumet conglomerate and the Osceola amygdaloid. The last two had proven paying lodes and the former had given promises of being rich at

some point. None of these lodes outcropped on their property, so in order to work them it was necessary to intersect them by vertical shafts.

They hit upon this plan and started No. 1 shaft as far to the east as was possible in order to strike these lodes the least distance from surface. They expected to cut the Allouez at 500 feet and the Calumet conglomerate at a depth of 2,000 feet from surface. That they were successful is putting it mildly. The Calumet conglomerate proved of high quality. Now they have five vertical shafts, one of which is the deepest in the world—No. 3 being bottomed at 5,229 feet, only 51 feet short of being a mile, below surface.

It was necessary for the Tamarack to use the vertical shaft. Other companies having copper bearing lodes on their property but not having the outcrop have adopted similar or different schemes, depending upon the circumstances. The Allouez does not carry any portion of the outcrop of the Kearsarge lode. Going as near as convenient to their eastern boundary they proceeded to sink a shaft at an angle of eighty degrees from the horizontal until the lode was encountered at a depth of 1390 feet. At this point, by using a curve seventy-five feet long the shaft was flattened to the plane of the lode which is 38½ degrees. The steeper portion of the shaft is provided with back runners to prevent the skip from jumping the track. So smoothly does the skip travel that these runners are rarely called into use.

Still another scheme was adopted at the Centennial. They owned the N. W. ¼ of N. W. ¼ of Section 18, T. 56 N., R. 32 W., and Section 12, T. 56 N., R. 33 W. The Kearsarge lode outcropped on their forty of Section 18 but being but 860 feet from the corner was not enough to make a mine. At this corner their part of the lode was squeezed to a point since the Calumet and Hecla owned the property to the south and the South Kearsarge to the north. They, however, bought a small strip of land from the South Kearsarge Mine and thus managed to get a width of 260 feet along the lode at this point. Two shafts were sunk from the outcrop through this narrow point. No. 1 shaft is straight and was sunk along the dip of the lode. No. 2 shaft, after passing the narrow point turned a little to the north and runs away from No. 1 shaft. This twist has caused the shaft to be likened to a cork screw.

Other factors for consideration are the disadvantages of using timber to support excavations and lining shafts. The copper country today is almost barren of big timbers. They have been used underground and in building construction. With this scarcity

comes the increase in price. Another objection is that it will not support an excavation for any length of time. The pressure in the deep mines is enormous. Assuming rock to weigh one hundred and fifty pounds per cubic foot we find that at a depth of 4000 feet there is a pressure of 600,000 pounds per square foot. Placing timbers far enough apart to allow room for working, what chance have they with such pressures? A common sight underground is to see timbers as much as two feet in diameter broken in two as one would break a twig. Another fault, and not by any means the least, is that wood is not fireproof. Some of our mines have been closed for long periods on this account. A fire broke out in the Tamarack on January 11, 1906, and burned in No. 1 shaft until August 1907. No. 2 shaft resumed operations a little over a year after the fire began.

Not only is the timber incapable of holding open the enormous workings of these mines but so is everything else. Pillars of rock left standing in the mines crushed within a certain time. Today the Atlantic is a wreck because the pillars would not support it. Thus the methods of mining have had to change. No longer do they expect large excavations to remain open. Neither can they allow a stope to remain idle any length of time. The mine must be worked steadily and the rock taken out while there is time. Typical methods of mining are to be described so as to illustrate these principles.

Unique in its conservative and economical methods stands the Wolverine. Here the dip is flat—being about 40°—so that the miners stand and set their machines on the foot wall. When the rock is broken, most of it rolls down the slope to the level. The roof is strong and no timber is used in the mine. Some pillars are left while men are working, but they are eventually taken out. Thus everything is removed except shaft pillars, leaving a large open stope. Without any support the roof in time falls and the opening becomes closed.

Next in order comes the method in use at the Calumet and Hecla mines. Here the slope is not much steeper than at the Wolverine, but the rock scales off and large slabs are liable to fall at any time from the hanging wall. This means that timbering must be used. The lode here averages a width greater than in most amygdaloid mines. To reach from foot to hanging would require long timbers of the finest kind. This being too expensive the square set timbering has been adopted.

In opening up the ground preparatory to working, a drift is run

in from the shaft half way to the other shaft. This distance in one case was six hundred and seventy-five feet. At the end of the drift a raise was started to run up to the next level. Two blocks three hundred feet long are then marked off and a pillar seventy-five feet thick is left to support the shaft. The block farthest from the shaft is then removed. As the work advances the timbermen follow them up so as to make the place safe for the workmen. When the first block is removed, the second block is attacked and the space left by the first block is allowed to fill by the crushing of the roof. These workings hold open but a short time. All the expensive timber simply serves for a short time. The two blocks are hardly removed before the whole stope begins to settle. The shaft pillar will only be removed when the shaft has reached the end of its usefulness. Then they will begin from the bottom to withdraw these pillars.

Great care is taken to prevent fires. Fire doors are erected in the drifts in the shaft pillar which can be readily closed. The timbers are all treated with a coating of chloride of zinc and then whitewashed.

In the Tamarack heavy stull timbers are used to support the hanging. Here also the timberman must follow closely upon the miners. "The copper bearing rock of the vein is all mined out as they go for the reason that the life of the timber is little more than a year, and it will not do to leave ground untouched too long after it is opened. They clean out the levels as they go downward letting the hanging come in as it will. The timbermen do much of the barring of loose ground in the hanging and act a very important part in the underground work."

The Atlantic was opened on an amygdaloid having a dip of 54° and an average thickness of fifteen feet. The copper is very evenly distributed. There is no selection of rock and almost all can be considered good stoping ground. In this mine work is entirely done by contract. The plan of working is as follows: Leaving a suitable shaft pillar, the ground is divided in 100 foot blocks and is let for those lengths. These contracts include drifting and stoping. First they cut out the drift, putting in heavy stulls, about twenty inches in diameter, to support the hanging and give a safe tramway. Lagging is then put on these stulls and the broken rock allowed to pile back of these. The miners getting on top of these timbers break away the rock. It accumulates on this lagging and the men stand on the broken product. This stoping is continued to within ten or fifteen feet of the level above. When a level on

one side of a shaft has been cut out, they begin to draw off the ore from the farthest end and work back towards the shaft. In this way they get out all the rock.

One of the latest methods adopted and hence one of the most interesting is the "Baltic Method" now in use at the Baltic, the Tri-Mountain and at the Champion mines. Here the lode averages thirty feet in width and in some places is wider. The dip of the lode is 72°. Thus it can be seen that no ordinary method of timbering could be employed. If overhand stoping is used something must be had for the miners to stand on in order to keep close to the back of the ore.

The copper is in pockets, being very rich in some places and lean in others. Some large masses have been taken from this lode. This fact has led to underground sorting and to filling the old stopes with the waste rock. The stoping starts right with the level itself and is cut out the full width of the lode. With the waste rock dry pack walls are built so as to keep open a place for tramming. This is covered over with heavy timbers and lagging and the waste rock is thrown around the walls and on top of the lagging. Thus the old stopes are kept filled with the waste rock. In order to dispose of the copper rock a mill is carried up at regular intervals from the drift and down this the copper rock is thrown. It is noteworthy that even these chutes or mills are built of pack walls. Owing to the inclination of the lode it is necessary to have both the drift and the mill built on the foot wall side of the lode.

The sorting is done by the sense of feeling rather than by sight. Copper in the rock very often cannot be seen but if the hand is rubbed gently over the surface of the rock the presence of copper is readily detected by the prickliness of the sharp particles of copper.

In this method they even take out the pillar between the levels. When the level above has been worked out and abandoned, the miners, starting at some one point blast out the pillar until they break through to the level above. This allows the loose rock to run through and spread itself as a cone on the broken rock below the pillar. The men then work on the sides of the cone and keep cutting back the pillar. The waste from the level above pushes the newly blasted rock to the base of the cone or wedge where it is sorted. Having mills at various points it is not necessary to commence this method of drawing pillars at the farthest end of the stope. Thus everything is cleaned out of the mine. The only pillars left in the mine are the shaft pillars but if the shafts were driven

far enough in the foot wall even these would not have to be left.

The advantages claimed by this method are the small amount of timber used, hence the lessened dangers of fire, the great safety to the men, no waste rock having to be hoisted to surface, and not having to leave pillars in the ground which may contain a large amount of copper.

To return to the general changes of mining it will be seen that as the mines grow deeper there is a marked tendency to have fewer shafts. This is particularly true of mines such as the Tamarack, which do not expect to work the ore body until they get quite a distance below surface. Having fewer shafts they naturally would be placed farther apart. This has led to the use of mechanical tramming underground. The Quincy has electric locomotives on some of the levels. In the Tamarack an endless rope system has been devised. This was first adopted in the long cross-cuts but within the last few years has been extended to use in the drifts themselves.

There has been another tendency which has largely counteracted the use of fewer shafts. This is an increased output. In 1875 the Calumet and Hecla produced about 21,000,000 pounds of copper while in 1906 the product was over 82,000,000 pounds of refined copper. The two tendencies have forced each shaft to do more work and consequently has led to the improvement of them. All shafts in producing mines have been enlarged to have a double skip compartment. Skips, instead of holding say one ton of rock are made for two or three in some of the mines, while those of the Quincy hold eight tons of rock.

Some of the mines hoist only from certain levels. This is true at the Quincy. Here the shafts are in the footwall. A pocket is cut in the footwall of the lode, or the hanging wall of the shaft. This pocket is filled from two or three levels above. At the level where the skip is to be loaded a chute is built directly above the track so that the skip is brought to this point, the lip of the chute is lowered and the rock runs into the skip.

The travelling of the skips at high speed is also causing its changes in the shafts. The road has had to be improved. If the rails were held loosely and were not smooth the skips would jump the track. These skip roads are constructed with the greatest care and are carefully watched. In two instances the use of wooden ties has been abandoned and the rails are laid on concrete stringers. These two mines are the Allouez and Baltic.

These concrete stringers are laid directly on the foot wall of the

shaft to which they are held by means of steel pins fastened into the foot wall and projecting into the concrete moulds. The concrete being laid around them, thus binds itself to the solid rock. They are usually one foot wide and the rail is bolted directly on its face.

The use of vertical shafts is another change. So far the only mine that has used a vertical shaft when not absolutely necessary is the Calumet and Hecla. The advantages of a vertical shaft are obvious. It gives a shorter way of getting to the ore body and allows of greater hoisting speed than does an inclined shaft (4,000 feet per minute at the Whiting shaft).

The No. 5 shaft of the Tamarack is a five compartment shaft, four of which are used for hoisting, the other being used for ladders and pipes. The Red Jacket shaft of the Calumet and Hecla is a six compartment shaft, the two easterly being used for ore, the westerly for hoisting and lowering men and materials, while the middle compartments are used for hoisting water.

The methods of hoisting ore at these vertical shafts are interesting. At the Tamarack, the tram cars themselves are hoisted in cages, which are used for all purposes, including the hoisting of men. The cages are double deck, thus two tram cars are hoisted at once. Each tram car holds three tons of rock, making a total of six tons hoisted at one time. At No. 3 Tamarack the capacity is about 1,000 tons daily. At the Whiting shaft, this method has been abandoned, owing to the time required in removing the cars, dumping and replacing them on the cage. Here the Kimberly skip has been adopted. This is a form of self dumping cage used in a vertical shaft. These have a capacity of nine tons each, thus allowing 4,000 tons to be hoisted from the one shaft during a period of 24 hours.

Vertical shafts are now being sunk by the Globe and Challenge mines. The reason for adopting them here is on account of the overburden. This is 125 feet thick at the Challenge and about twice that thickness at the Globe. In both cases drop shafts were used in order to get to the ledge and these being vertical the shafts through the rock were continued vertically downward.

To allow the shafts to be run to their capacity, new methods have had to be adopted in getting the men in and out of the mines quickly and without tiring them. While ladders are placed in every mine, being required by law, they are used only by men working on the upper levels or for going from one level to another. It would take too long and prove too tiresome for a man on the

lower levels of the Calumet and Hecla to climb say 8,100 feet of ladders. Another of the pet schemes of a decade ago has also been abandoned. This is the man-engine.

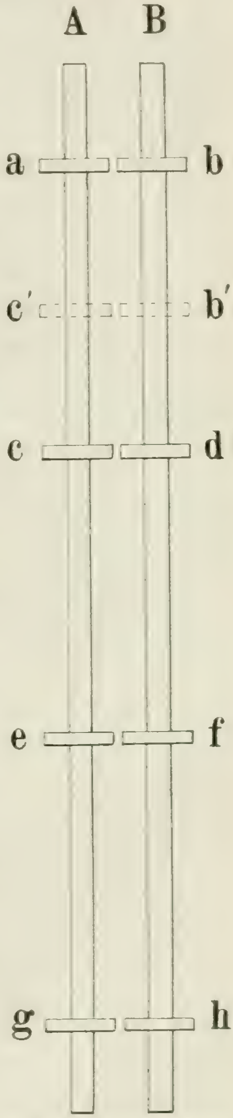

Fig. 67. Sketch of man-engine.

A brief description of this machine might be introduced to show the ingenuity of the device and also to show its defects. Primarily it consists of two reciprocating rods A and B (Fig. 6) extending into the mine. Each rod has platforms a, c, e, g and b, d, f, h placed at equal intervals apart—generally twelve feet—but always twice the length of the stroke. On each platform there is an upright rod by which the men can steady themselves in ascending or descending. The action can best be described from the diagram. A man wishing to descend is standing on platform a. He steps on platform b when it is opposite him. The rod B then descends until platform b is at b′. In the meantime rod A has ascended so that platform c is in position of c′ or opposite b′. The man steps over to the platform c which then descends and allows him to step to platform d. In this way he is carried into the mine. By reversing the operation he is carried up. The engine operating the two rods is usually governed by a fly wheel so that the speed of the strokes is most rapid in the center of the stroke, slowing down to a stop when the two platforms are together.

Such a machine may be adopted in either a vertical shaft or in an inclined one. It is, however, clumsy and costly in the first place, in operation, and in repairs. It is not safe as men have often become dizzy and confused. Besides this it does not save much more time, if any, than does the old fashioned ladders.

The universal practice now is to hoist and lower men in either cages, skips or man-cars. In the vertical shafts and in the more steeply inclined shafts, as the Baltic and Champion cages are used. These are generally double deck affairs, so that from 20 to 30 men can be hoisted at

once. The older practice in the inclined shafts was to allow the men to ride up and down in the skips. They would pile into these until one would wonder how so many human beings could get into such a small space. When they get to surface they are very often jammed in so tight that one man has to be pulled out before the others can be loosened so that they may help themselves.

The man-cars can be likened to a set of steps set on wheels. These are wide enough to accommodate three men to a step and being ten steps long hold 30 men when full. It is an interesting operation to watch them remove the skip from the track and place the man-car there. At the Quincy there are four cranes to the shaft, two for each hoisting compartment. One of these removes the skip from the track. The other holds the man-car. This is then swung to the track, the rope fastened to it and the man-car is then lowered into the mine. The time required to make the change is less than one minute.

Some of the mines have special shafts, as the Wolverine, or special compartments of the shaft for hoisting and lowering men. In these cases this operation does not interfere with the hoisting of ore. It is noteworthy that the Calumet and Hecla have special ropes and special engines for hoisting and lowering the men.

These extensive improvements underground have led to improvements on surface. Separate shaft and rock houses connected by the Frue Automatic tramway are very seldom seen. Now that one shaft has a capacity equal to that of an entire mine in 1875 it has been found necessary to combine the two and have one rock house for each shaft. The sorting and crushing have changed but little. For the same reasons that wood is being abandoned underground it is being replaced by steel in surface construction. Gradually steel shaft houses are replacing the old wooden ones. With the use of steel comes a change in shape. The bins to the rock houses are being made circular. This is due to the greater ease of spreading the ore and entirely filling bins of this shape.

The hoisting engine has risen from one of forty horsepower with a six or eight-foot drum as a maximum to one of eight thousand horsepower with a twenty-four foot drum at a few of the mines. These first engines simply operated one skip, hoisting them to surface and by releasing the break, allow them to run back into the mine. Now each hoist controls two skips with their ropes so wound on the drum as to allow one skip to descend while the other ascends. This is known as hoisting in balance since the weight of the skips are equalized, thus giving less work for the

engine to perform. At the Red Jacket shaft of the Calumet and Hecla the weight of the rope is also equalized by hanging the ends of a rope to each cage and allowing it to pass to the bottom of the shaft. The hoist here is peculiar being the only one of its kind in the copper country. The large drum has been discarded and instead two drums of a narrow face have been used. Only one hoisting rope is used. This is connected at one end to one cage. It passes around the two drums three or four times, then back into a tail house where the proper tension is kept and at last connected to the other cage. To these two cages is hung the tail rope. The whole system may be likened to a cable car system.

Where the large drum is still used we often see, instead of a flat faced drum, a double conical drum with the rope so wound on it that when the skip is hoisted and the weight becomes less the rope is wound on a constantly increasing diameter, thus increasing the speed of the skip and keeping the strain on the engine more constant. These conical drums have their friends and enemies and much can be said for and against them.

The engineer no longer sits on the brake lever in order to stop his engine. Steam cylinders now control the brake so that an engineer merely operates a lever. By means of floating levers and oil cylinders the pressure of the break is very closely regulated.

The floating lever is used to regulate the oil and steam cylinders, operating the break and receives its name because the fulcrum is not a fixed point. This lever is held by three rods at points A, B, and C of the diagram. The rod attached at B is connected to and operated by the engineer's lever. The rod connected at C is connected to and operated by the piston rod of the steam cylinder operating the brake. The rod A operates the valves to the oil and steam cylinders.

If the engineer wishes to lift the piston rod he lifts, by his lever, the point B to the position of B′. C now acts as the fulcrum, AC as the lever arm, and the lever assumes the position A′ B′ C. The rod at A, being lifted, allows the steam to enter below the piston and it rises, pushing the rod connected at C with it. Now B acts as the fulcrum and the lever assumes the position AB′ C′. Thus the rod A is pushed back to its original position closing off the steam from the steam cylinder. In order, however, that the expansion of the steam in the cylinder will not carry the point C too far the piston rod of the steam cylinder is made to operate through an oil cylinder and when the rod at A shuts off the steam it also closes the valves for the oil cylinder and thus locks the

piston. The distance which the point C moves is in direct proportion to the distance which B moves. As the brake moves proportionately to C and B moves proportionately to the engineers lever it is possible for him to regulate the pressure of the brake very readily. To reverse, the point A must be pushed down to point A″.

Safety devices now form a part of all hoists. By means of a worm screw the steam is thrown off and the break set when the skip reaches a certain place, thus preventing overwinding. There are two dials on each engine marking the position of the skips in the shafts. This of course is merely approximate. On the drum itself are marked in chalk the exact positions at which it should be stopped so that the skip can be exactly stopped at any desired level.

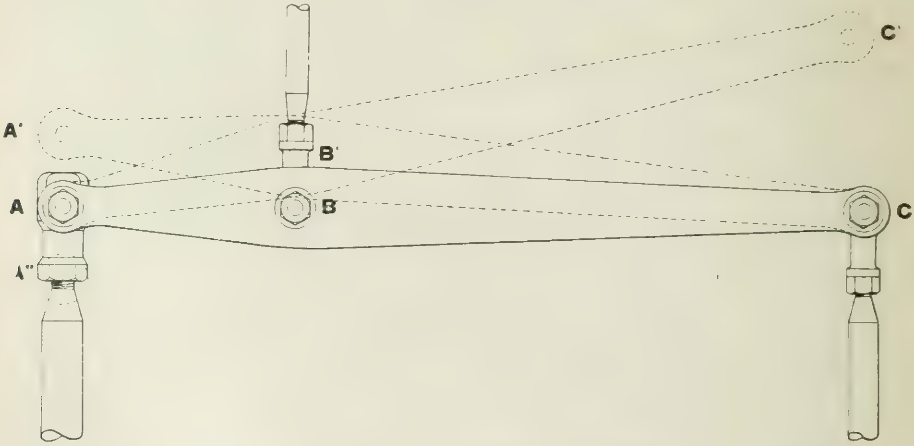

Fig. 68. Floating levers. Sketch by A. H. Meuche.

Before closing, a few remarks on drainage may not be out of place. Fortunately this is not much of a problem for the copper mines. One or two of the mines have their upper levels drained by adits. Most of the water in the mines is surface water and flows in on the first thousand feet of workings. Below this the water is very acrid in character, so much so that pumps and pipes are readily coated with rust. The amount of water is very small and does not pay for the installation of pumps on these lower levels. Most of the deeper mines, such as the Tamarack, Calumet and Hecla, and Quincy, allow this "mine water" to collect in sumps at the bottom of the shafts and bail it out in large bailers.

The stamp mill practice has changed but little during the past

thirty years. The greatest change has been in decreasing the cost of production by increasing the capacities of the various units. The steam stamp of today, with the aid of rolls have a crushing capacity of over 700 tons. This stamp is fed from a hopper by gravity into this stamp. A man with an iron hook stands here to regulate the feed or hold it back when necessary. He also watches for pieces of mass which he casts aside. The total crushing or falling weight is three to four tons and the actual stroke is from 20 to 24 inches.

In the mortar (at the Isle Royale mill) the rock is crushed to pass a five-eighths inch screen. Large lumps of copper, the size of small potatoes which are contained in the rock will not pass this screen. They are removed by a hydraulic arrangement. A four inch opening is left in the mortar just below the lip. This is connected to a pipe through which water is forced into the mortar at such a speed that only these lumps of copper can force themselves through it. They fall into a receptacle outside of the mortar. These are termed headings and make up about one-fourth of the product of the mill. Another and almost equal amount is extracted between the stamps and the trommels.

The annexed flow sheet will serve the purpose of tracing the product through the mill. The rock after leaving the stamp goes to a trommel with a 5/16″ hole. The oversize passes to a set of rolls and is crushed to a smaller size. The ore then passes to a hydraulic classifier. In each section of the mill there are three such classifiers with three sets of roughing jigs, each doing the same work. The rock from the trommel is divided into three equal parts, each of which goes to a classifier. In these classifiers the rock is classified into five parts, the heaviest settling first and so on until the fifth or slimes is washed over the end and taken to settling tanks. The other products are jigged on two separate jigs, the hutch of which goes to the finishing jigs and the tails are waste. A certain amount of copper collects on the screens of the jigs and is scraped off at regular intervals. The hutch product of the finishing jigs runs to settling boxes and is ready for the smelter or subsequent treatment. The slimes are first allowed to settle. The settlings are treated on Evans tables the heads of which are treated on Wilfley or Overstrom tables and the tails go to waste.

In the operation of the stamp mill copper is taken off at every point. It is picked from the feeding hopper, discharged in big lumps from the stamps. It comes from the roughing jigs as red gravel, as fine sand from the finishing jigs and as red mud from

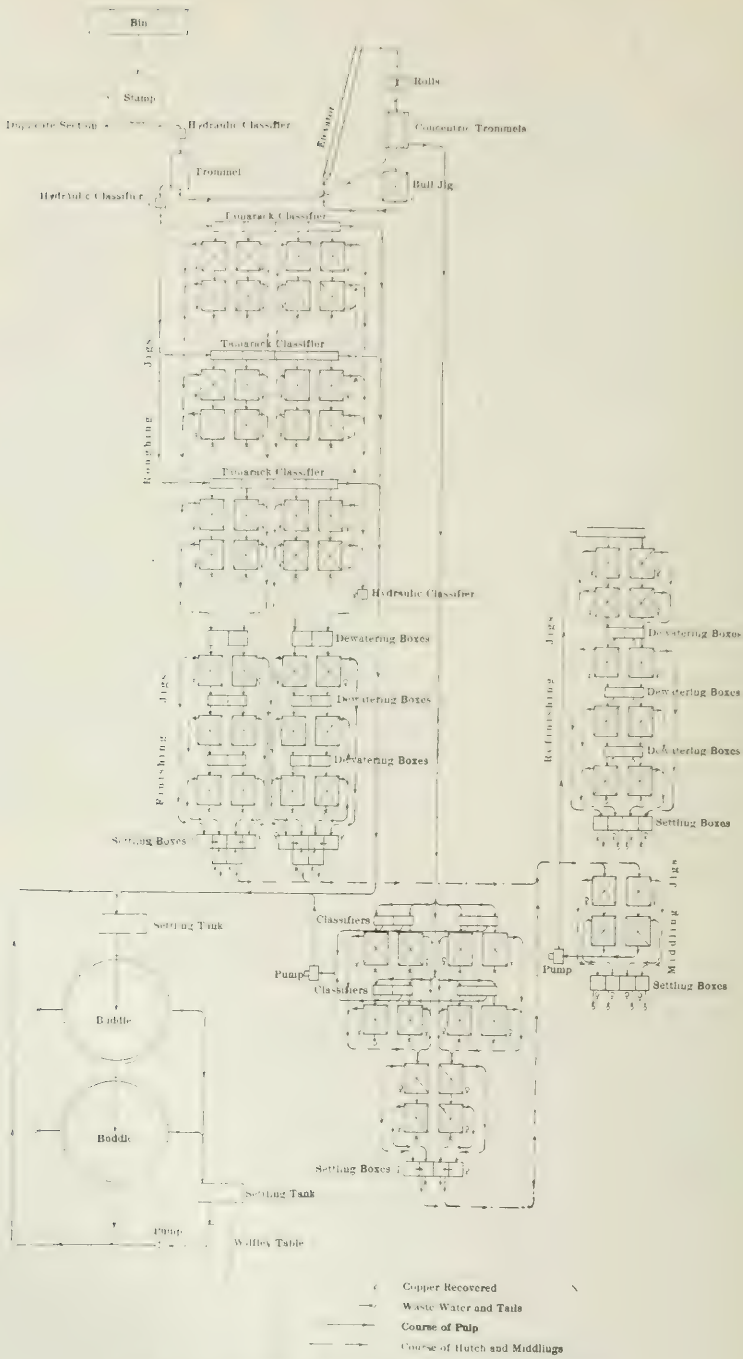

Fig. 69. Flow sheet of Stamp mill. Sketch by Meuche.

the concentrating tables. Some native silver is found with the copper. At some stamp mills a boy is employed to pick silver out of the mineral but if the pieces are very small but of rather high percentage (2%) the mineral is refined at the smelter and cast into anodes. These are then shipped to an electrical refinery where the silver and copper are separated. No reliable estimate can be made of the amount of silver in these mines as it is stolen by the employees underground, in the mills, and smelters.

The amount of water used is something enormous, being something like thirty tons of water to one of ore or three and one-half million gallons per day for each stamp. The cost of stamping has been reduced from two dollars a ton in 1854 to as low as twenty-eight cents. (Tamarack report for 1907.)

It must not be supposed that all the copper is recovered. The criticism of Prof. Egleston still holds and as stated by a more recent writer: "This will emphasize the observation that during late years the endeavor to lessen costs has been pushed at the expense of any improvement in extraction; that is, it has not realized that while the expenditure entailed by the treatment of copper ore has decreased, there has been no commensurate diminution in the amount of copper lost. Five cents worth of copper, per ton, lost in the tailing is worth just as much as a five cent decrease in milling cost."

APPENDIX.

BY A. C. LANE.

1. *Introduction.*

Between the writing of so voluminous a report as this and its actual issue, some time must elapse. This report is part of my report for the year 1909. I had to make a hard and fast rule, in order to ever get through, in reading proof, to make no changes, except where actual errors or failures to clearly convey my meaning were involved. The temptation was strong to try to include more recent drilling, but as dozens of drills had been and are continuously at work, I should never have known where to stop. The wisdom of this rule is shown by one of the few exceptions made to it. In a few cases, where I thought the reader should be forewarned of a change of views or different use of names due to it, more recent work has been mentioned. One of these references, that to the "Mayflower lode" in the foot-note of page 371, called attention to the fact that the lode recently so named is not the one so named in Figure 39 and in earlier explorations. But, misled by press accounts of recent drilling, I misstated the horizon of the new "Mayflower lode," which, according to G. S. Goodale, in the annual report of the Company for 1911, is several hundred feet below the St. Louis conglomerate.

A few reports have, however, appeared since the transmission of my manuscript and a few explorations of such importance made that I have inserted this appendix, so that, although I may not give them all the attention they merit, I may not seem to ignore them.

2. *Bibliography.*

I have not given a complete bibliography of titles pertaining to the Keweenawan series. Work thereon is so covered by the reports of the Canada, Ontario, Minnesota, Wisconsin and Michigan Geological Surveys, and especially the bibliographies of Monographs 5 and 52 of the United States Geological Survey, and its annual bibliographies, that it would be what R. S. Woodward has called "a platitude of research." I have, however, listed a few

papers overlooked in the bibliographies and some of the more recent works to which I would call attention.

The Proceedings of the Lake Superior Mining Institute, the Canadian Mining Institute, the American Institute of Mining Engineers and the Michigan Academy of Science will naturally not be over looked by the thorough enquirer. The Michigan Engineering Society and Michigan Miner mainly concern themselves with Lower Michigan.

The losses in copper dressing at Lake Superior, by Adjunct Professor H. S. Monroe. Transactions of the American Institute of Mining Engineers, September, 1879.

The copper-bearing rocks of Lake Superior, by R. D. Irving. U. S. G. S. Monograph V; also 3rd annual report U. S. G. S., 1883, pp. 93-188.

Geologic maps of Michigan, by Jules Marcou and John Belknap Marcou. U. S. G. S. Bulletin No. 7, 1884, pp. 77, 78, 79, 80, 81, 82, 83, 85, 87, 88.

On the classification of the early Cambrian formation, by R. D. Irving. U. S. G. S. 7th Annual Report, 1888, pp. 365-454.

Notes on some diabase dykes of the Rainy Lake region, by Andrew C. Lawson. Proceedings Canadian Institute, 1887.

Las aguas minerales de Chile, by Dr. L. Darapsky. Valparaiso, 1890.

The copper region of Michigan, by Frank B. Phelps. Engineering Magazine, Vol. IV, 1892, pp. 47-63.

Building stone from Michigan, at World's Columbian Exposition. M. R., 1893, p. 567.

Excursion to Lake Superior—Pre-Cambrian geology of the Lake Superior district, by C. R. VanHise. Int. Cong. Geol. Compte Rendu, 5th session, 1893, pp. 110-50.

Basic massive rocks, by W. S. Bayley. Journal of Geology, Vol. I, 1893, pp. 433-56, 587-96.

On powellite from a new locality, by George A. Koenig and L. L. Hubbard. American Journal of Science, 3rd ser., Vol. XLVI, 1893, pp. 356-8.

The copper resources of the United States, by James Douglas. Sci. Am. Suppl., Vol. XXXV, 1893, pp. 14183-6.

A reconnaissance of the abandoned shore lines of the south coast of Lake Superior, by F. B. Taylor. American Geologist, Vol. XIII, 1894, pp. 365-83.

Ueber powellit von einem neuen Fundorte, by Georg A. König

and Lucius L. Hubbard. Zeitschrift für Krystallographie, etc., XXII 5 6 1894, pp. 463-6.

Changes of level in the region of the Great Lakes in recent geological time, by F. B. Taylor. American Journal of Science, 3rd ser., Vol. XLIX, 1895, pp. 69-71.

On underground temperatures at great depth, by A. Agassiz, American Journal of Science, 3rd ser., Vol. L, 1895, pp. 503-4.

A northern Michigan base-level, by C. R. Van Hise. Science, new ser., Vol. IV, 1896, pp. 217-20.

A central Wisconsin base-level, by C. R. Van Hise. Science, New ser., Vol. IV, 1896, pp. 57-9.

The crystallization of the calcite from the copper mines of Lake Superior, by Charles Palache. Michigan Geological Survey, Vol. VI, Pt. II, Appendix, 1898, pp. 161-84.

The origin and mode of occurrence of the Lake Superior copper deposits, by M. E. Wadsworth. Transactions American Institute of Mining Engineers, Vol. 27, 1898, pp. 669-96.

Some dike features of the Gogebic iron range, by C. M. Boss. Idem. pp. 556-63.

On the thermal conductivities of certain poor conductors, by B. O. Peirce and R. W. Willson. Proc. Am. Acad. Arts and Sciences, Vol. XXXIV, No. 1, 1898, pp. 3-56.

Powellite crystals from Michigan, by Charles Palache. American Journal of Science, Vol. VII, May 1899, pp. 367-9.

Altitudes in Michigan. U. S. G. S. 21st Annual Report, Pt. I, 1899-1900, p. 465.

Note on a method of stream capture, by A. C. Lane. G. S. A. Bulletin, Vol. X, 1899, pp. 12-15.

The development of the copper industry of Northern Michigan, by James Ney Wright. Michigan Pol. Sci. Ass. Pub., Vol. 3, No. 5, Ann Arbor, 1899.

On the thermal diffusivities of different kinds of marble, by B. O. Peirce and R. W. Willson. Proc. Am. Acad. Arts and Sciences, Vol. XXXVI, No. 2, 1900, pp. 13-16.

On mohawkite, stibiodomeykite, algodonite and some artificial copper-arsenides, by George A. Koenig. American Journal of Science, Vol. X, December 1900, pp. 439-48.

Note sur la région cuprifère de l'éxtremiteé nordest de la péninsula de Keweenaw (Lac Supérieur), by Louis Duparc. Archives sci., phys. et Nat., Vol. X, 1900, p. 21.

The geothermal gradient in Michigan, by A. C. Lane. American Journal of Science, 4th ser., Vol. IX, 1900, pp. 434-8.

The origin of the native copper in the Michigan deposits, by J. F. Blandy. Engineering and Mining Journal, Vol. XX, 1900, pp. 278-9.

Suggestion from the State Geologist, by A. C. Lane. Michigan Miner, Vol. 3, No. 10, 1901, p. 9.

Annual report of the State Geologist (Michigan), by A. C. Lane. Michigan Miner, Vol. 3, 1901, pp. 13-22.

Work of the Geological Survey in the Upper Peninsula, by L. L. Hubbard. Michigan Miner, Vol. 3, No. 3, 1901, p. 9.

Geological Survey of Michigan. Report of field work for 1900, by W. V. Savicki. Idem. pp. 9-11.

On artificial production of crystallized domeykite, algodonite, argentodomeykite and stibiodomeykite, by George A. Koenig. Proceedings Am. Philosophical Society, Vol. XLII, No. 173, pp. 219-37.

Crystallographic properties, by F. E. Wright. Idem, pp. 237-49.

On the thermal conductivities of certain pieces of rock from the Calumet and Hecla mine, by B. O. Peirce. Proceedings American Academy of Arts and Sciences, Vol. XXXVIII, No. 23, 1903, pp. 651-60.

Copper mining in Upper Michigan, a description of the region, mines and some of the methods and machinery used, by J. F. Jackson. Mines and Minerals, Vol. 23, 1903, pp. 535-40.

The theory of copper deposition, by A. C. Lane. Michigan Miner Vol. 6, No. 2, 1904, pp. 9-11, No. 3, pp. 9-11; American Geologist, Vol. 34, 1904, pp. 297-309.

Copper mines of Lake Superior, by T. A. Rickard. Engineering and Mining Journal, Vol. 78, 1904, pp. 585-7, 625-7, 665-7, 705-6, 745-7, 785-7, 825-7, 865-7, 905-7, 945-50, 985-7.

The geology of some of the lands in the Upper Peninsula (Michigan) by R. S. Rose. Mining World, Vol. 21, 1904, pp. 205-7; Engineering and Mining Journal, Vol. 78, 1904, pp. 343-4; Proc. Lake Superior Mining Institute, pp. 88-102. See Monograph LII.

Historical review of the geology of Michigan, by A. C. Lane. Michigan Academy of Science, 5th Annual report, 1904, pp. 184-95.

Comment on the "Report of the special committee on the Lake Superior region," by A. C. Lane. Journal of Geology, Vol. 13, 1905, pp. 457-61

The Tamarack Mine cross-section and the Keweenawan lodes, pp. 271-94; also—

Waters of the Upper Peninsula of Michigan, pp. 111-67; also—

Report of progress in the Porcupine, by F. E. Wright. Michi-

gan Geological Survey, Annual Report for 1903, 1905, pp. 33-44. Also preliminary geological map of the Porcupine Mts. and vicinity, by F. E. Wright and A. C. Lane. Michigan Geological Survey, Annual Report for 1908, 1909, Plate I.

Notes on the rocks and minerals in Michigan. To accompany the loan collection issued by the Michigan College of Mines, by F. E. Wright, Houghton, 1905.

Mines of the Lake Superior copper district, by Horace J. Stevens. Program for 12th Annual meeting Lake Superior Mining Institute, 1906, pp. 9-27; also Proc. Lake Superior Mining Institute, Vol. 12, 1907, pp. 8-24.

An ecological survey in the Porcupine Mts. and Isle Royale, Michigan, by A. G. Ruthven. Michigan Geological Survey, Annual Report for 1905, 1906, pp. 17-47.

The copper mines of the United States in 1905, by W. H. Weed. U. S. G. S. Bulletin No. 285, 1906, pp. 93-124.

The Nonesuch sandstone, by G. W. Corey. Engineering and Mining Journal, Vol. 82, 1906, p. 778.

Material for geography of Michigan, by M. S. W. Jefferson, Ypsilanti, Michigan, 1906.

Peat, essay on its origin, uses and distribution in Michigan, by C. A. Davis. Michigan Geological Survey, Report of State Geologist for 1906, 1907, pp. 93-395.

The Newark (Triassic) copper ores of New Jersey, by J. Volney Lewis. Annual report of New Jersey State Geologist, 1906, pp. 131-64.

Die Enstehung der Kupfererzlagerstätte von Corocoro und verwandter Vorkommnisse in Bolivia, by G. Steinmann. Festschrift Harry Rosenbusch, Stuttgart, 1906, pp. 335-69.

Copper deposits of the New Jersey Triassic, by J. Volney Lewis. Economic Geology, Vol. II, No. 3, 1907, pp. 242-57.

Structure and correlation of Newark trap rocks of New Jersey, by J. Volney Lewis. G. S. A. Bulletin, Vol. 18, No. 4, 1907, pp. 195-210.

Ninth annual report of the State Geologist of Michigan for the year 1907, by A. C. Lane. State Board Geological Survey report, for 1907, 1908, pp. 1-31.

A reconstruction of water planes of the extinct glacial lakes in the Lake Michigan basin, by J. W. Goldthwaite. Abstract: Science, new ser., Vol. 27, May 8, 1908, pp. 724-5; Journal of Geology, Vol. 16, No. 5, 1908, pp. 459-76.

The altitude of the Algonquin beach and its significance, by J.

W. Goldthwaite. Abstract: Science, new ser., Vol. 28, Sept. 18, 1908, pp. 382-3.

Features indicative of physiographic conditions prevailing at the time of the trap extrusions in New Jersey, by C. N. Fenner. Journal of Geology, May-June, 1908, pp. 299-327.

Use of "ophitic" and related terms in petrography, by A. N. Winchell. G. S. A. Bulletin, Vol. 20, 1908, pp. 661-67.

In the Michigan copper country, by R. E. Hore. Canadian Mining Journal, Vol. 30, July 15, 1909, pp. 421-2.

Michigan iron mines and their mine waters, by A. C. Lane. Mining World, Vol. 31, August 21, 1909, pp. 413-16.

Geology of the Porcupine Mts., Michigan, by A. C. Lane. Mining World, Vol. 30, June 12, 1909, pp. 1115-17.

The decomposition of a boulder in the Calumet and Hecla conglomerate and its bearing on the distribution of copper in the Lake Superior copper lodes as indicating the trend and characters of the waters forming the chute, by A. C. Lane. Economic Geology, Vol. 4, No. 2, 1909, pp. 158-73.

Mines waters and their field assay, by A. C. Lane. Geol. Soc. Am. Bulletin, Vol. 19, 1909, pp. 501-12.

Tenth annual report of the State Geologist of Michigan to the Board of Geological Survey for the year 1908, by A. C. Lane. Michigan Miner, Vol. 11, No. 2, Jan. 1909, pp. 9-17.

Salt water in the Lake mines, by A. C. Lane. Michigan Miner, Vol. 11, No. 4, March, 1909, pp. 24-26.

The Watchung basalt and the paragenesis of its zeolites and other secondary minerals, by Clarence N. Fenner. Annals of the New York Academy of Science, Vol. XX, No. 2, Pt. II, Aug. 4, 1910, pp. 93-187.

The crystallization of a basaltic magma from the standpoint of physical chemistry, by Clarence N. Fenner. American Journal of Science, Vol. XXIX, March, 1910, pp. 217-34.

Copper-bearing amygdaloids of the White River region, Alaska, by Adolph Knopf. Economic Geology, Vol. V, No. 3, April 1910, p. 247. See also U. S. G. S. Bulletin No. 417, Moffit and Knopf.

Copper, a weekly review of the Lake Superior Mines, (published by Gay and Sturgis, A. L. Carnahan, Editor), Vol. 3, No. 23, September 3, 1910.

Copper in the red beds of Oklahoma, by William Arthur Tarr. Economic Geology, Vol. V, No. 3, April, 1910, p. 221.

Ein Beispiel der "Zeolith-Kupfer-Formation" in Andesit-Massiv

Osterbeins, by Stud. M. Lazarevic Leoben. Zeitschrift für Praktische Geologie, February, 1910, p. 81.

Das Vorkommen und die Gewinnung des Kupfers, by Prof. Dr. Krusch. Naturwissenschaftliche Wochenscrift, Nos. 51 and 52, December, 1910.

The effect of leakage at the edges upon the temperatures within a homogeneous lamina through which heat is being conducted, by B. Osgood Peirce. Proc. American Academy of Arts and Sciences, Vol. XLV, No. 13, April, 1910, pp. 355-60.

The geology of the Lake Superior region, by Charles R. Van Hise and Charles K. Leith. U. S. G. S. Monograph LII, 1911. Chapter IV (Physical Geography) by Lawrence Martin; W. J. Mead, R. C. Allen, A. N. Winchell and Edward Steidtmann also mentioned in the table of contents as co-authors.

Some modes of deposition of copper ores in basic rocks, by Waldemar Lindgren. Economic Geology, Oct.-Nov., 1911, Vol. VI, No. 7, pp. 687-700.

The Copper Handbook, by Horace J. Stevens, 1900-1911 inc.

Some practical suggestions for diamond drill explorations, by A. H. Meuche. Lake Superior Mining Institute, Vol. XVI, 1911, pp. 77-81.

Genesis of copper with zeolites in basic rocks, by Waldemar Lindgren. Mining and Engineering World, Vol. 35, No. 27, Dec. 30, 1911, p. 1311.

Appraisal of mining properties of Michigan by the State Board of Tax Commissioners, 1911, by J. R. Finlay.

Native copper in basalt, by R. Braums in Bonn. Zeitschrift für Krystallographie, 1911, p. 493; Central Blatt, 1908, pp. 705-9.

The copper-mining industry of Michigan, by R. E. Hore. Mining World, Vol. XXXVI, No. 11, 1912, pp. 601-3, No. 12, pp. 656-58, No. 13, pp. 707-10, No. 14, 763-67.

Notes on the paragenesis of the zeolites, by J. Volney Lewis. Preliminary list of papers for 24th meeting of G. S. A., Dec. 27-30, 1911, p. 5; also Science, February 23, 1912, Vol. XXXV, p. 313.

Diamond drilling at Point Mamainse, Province of Ottawa, by A. C. Lane. Bulletin 6, Department of Mines, Canada, 1912.

Divergences.

It would be pleasant and not profitless to point out in detail where the observations herein recorded confirm, agree with and strengthen the conclusions of Fenner and Lewis in New Jersey and of Van Hise, Leith, Steidtmann, Martin and Thwaites on the

Keweenawan. I shall do this to some extent by seeing that not merely their names are thoroughly indexed, but also certain headings under which are grouped references to observations on subjects of especial interest to them, such as: prehnite and other zeolites, paragenesis of; Keweenawan, signs of origin of; Upper distribution and relations; water, effect of; copper, formation of.

Although less pleasant, it may be of more use to point out wherein there are divergences, so that the reader of this report may be duly warned thereof.

With Monograph LII, there are three main points of divergence; (1) as to the intrusive character of the Greenstone[1]; (2) as to the age of the Keweenawan; (3) as to the age and connate character of the salty mine waters.

As to the Greenstone, the authors of Monograph LII, on page 381, cautiously suggest that it may be, at least in part, intrusive. The coarseness of the grain of this, perhaps the coarsest single lava flow that is known, and the cliffs above the Cliff Mine, like those of the intrusive Palisades of the Hudson, make the suggestion natural. But, on the other hand, we have the following facts:

(a) So far as it is always at one horizon, just above the Allouez conglomerate, and never seems to cut across strata we have a very strong argument for its being a flow. How far this is true can only be judged by a detailed study of Chapter V. The authors of Monograph LII are hardly inclined to accept my correlations of exact beds of the section on Isle Royale with beds on Keweenaw Point; (b) it has not the contact effect of the igneous rocks, neither producing tourmaline as under the Palisades nor changing augite to such hornblende as produced in the ophites by the gabbro of Mt. Bohemia; (c) the occasional induration, and especially the occasional production of steam bubbles in the originally muddy upper layers of the bed below, which are now filled with calcite, are quite characteristic of an effusive contact; (d) the coarseness of the grain clear to the center is much more likely to occur in a thick flow than in a thick sill, as shown in Chapter IV; (e) even the lighter streaks, the diorite streaks of Marvine, or doleritic streaks, in which the feldspar is coarser than in many gabbros, show by the fact that the nearer they are to the center of the Greenstone as a whole the coarser they are, while they show no change in coarseness in their contact with the darker, poikilitic part, that they are an essential part of the original flow. They do, indeed, look very much like some gabbro pegmatites, and are,

[1]Note the capitol. The term is used on Keweenaw Point as a proper name applied to the bed above the Allouez Conglomerate.

I believe, due to a similar segregation of mineralizers, which tended to produce a greater power of crystallization and more perfect crystals, and possibly delayed, also, the crystallization. For details regarding this, see the references indexed under Greenstone, doleritic texture, Allouez conglomerate.

(2) As to the age of the Keweenawan, owing to the work of Thwaites, we are now happily agreed as to almost all the facts summarized on pages 416 to 426 of Monograph LII. I still adhere to the conclusion of my report for 1908, drawn from these facts, that the Cambrian age of the Keweenawan is probable. That the Keweenawan is "largely subaerial" and (naturally therefore) "not fossiliferous," I find no argument against its Cambrian age, but quite the reverse. That the Cambrian contrasts with the Keweenawan in lacking volcanism, is certainly not true of the Upper Keweenawan, which is later than any volcanism in the Lake Superior region, unless, indeed, Wilson's suggestion that there are Cretaceous lavas near Nipigon Bay should prove to be correct. (Monograph LII, p. 369.) On the other hand, the early Cambrian of eastern Canada and New England, as well as the typical Welsh Cambrian, contains coeval volcanics. This does not show anything as to Lake Superior of course. I only wish to point out that the statement of Monograph LII must be qualified until it, too, does not prove anything. Though the "Upper Cambrian is flat lying," so is the Lake Superior sandstone of the Apostle Islands, which Thwaites recognizes as conformably above and part of the Upper Keweenawan. That the upper marine Cambrian rests unconformably upon Middle Keweenawan beds is quite to be expected, when the latter are land volcanics.

"The similarity of lithology and accordance of structure between Upper Keweenawan and Cambrian" might, indeed, be the result, as the authors say, of a very much later transgression of the sea over flat lying sediments, but since the Lake Superior basin began to form before the Keweenawan, and seems to have never ceased to be a basin, there should have been continuous deposition in the center. This would be true whether it were a marine or a desert basin, a bolson or a playa, and this, indeed, seems to be accepted by the authors of Monograph LII, in their resumé (on page 416) of the course of events, but in that case, the whole Cambrian must be represented in the series of red sediments between the Jacobsville sandstone and the Freda sandstone, which can hardly be more than a few thousand feet, while Walcott gives for the Cambrian section of the Rocky Mountains (National Geographic Magazine,

Vol. 22, No. 6, p. 514) 3,590 feet Upper Cambrian, 4,963 feet Middle Cambrian, 4,524 feet Lower Cambrian, largely limestones and shales, which are generally supposed to be very much more slowly accumulated than the sandstones. Under any hypothesis, the Keweenawan beds "constitute a marked local variation" from general conditions, but to me they seem lithologically far more allied with the Upper Cambrian than with the Pre-Cambrian. This is shown by the fact that for a long while almost everyone supposed that the Bayfield or Western sandstone of the Apostle Islands was of the same age as the Jacobsville or Eastern sandstone, which the Limestone Mt. section seems to show to be Cambrian.

Again, not only the Porcupine Mt. monadnocks referred to by Van Hise, which, as he says, were (Science, new ser., Vol., IV, 1896, pp. 57-9) more nearly reduced to base-level during a time extending down to the Cretaceous, but numerous contacts of the Jacobsville sandstone that show relations of contact against cliffs of the Lower Keweenawan beds, while they indicate, indeed, much erosion during intervening time, also seem to me to indicate that the Lower Keweenawan was by no means base-leveled at the time of the Upper Cambrian transgression nor lay beneath the Pre-Cambrian peneplain. But the profound discordance of the Keweenawan and Huronian on the Gogebic Range and not merely that, the whole relation of distribution and attitude of the Keweenawan to the Huronian folds and formation, as A. E. Seaman has suggested, seems to show almost at a glance relations like those of the Triassic sandstones and traps (which the Keweenawan so much resembles) to the Palaeozoic. The main movement, much folding, many synclinal axes, much iron ore concentration, much erosion, took place before the Keweenawan. In other words, the master gap, at the beginning of the Palaeozoic, comparable to that at the end of the Palaeozoic, occurred prior to the Keweenawan, rather than after. The problem thus seems to be analagous to that of the "Red Beds" of Pennsylvania-Permian-Triassic age. Final conclusions must come from a valid correlation of volcanic outbursts, continental uplifts, and world-wide changes of strand line. The nearer we can get marine Cambrian, in which there are signs of contemporaneous volcanic action, the surer we shall be that the Keweenawan volcanics are Cambrian in age.

Seaman's map of the Keweenaw Point district (Plate XXVIII, Mono. LII) seems to draw the line between Upper and Lower Keweenawan at the base of the Great Conglomerate,—a suggestion

stratigraphically worthy of consideration, though it does not accord with Irving's original division, nor with the text.

M. Collen in Economic Geology, 1907, page 572, (Vol. II, No. 6) describes a series of copper deposits in the Belt formation of Montana. This is unconformably overlaid by the Middle Cambrian, Flat head sandstone, and is said to be separated by great unconformities both from it and the "Archean" beneath. It is divided into two series by an unconformity. The upper and lower series contain black fetid limestones, and certain beds of this are impregnated with chalcopyrite and chalcocite. There is also a great thickness of red shale,—the Spokane shale. These red beds carry copper ores sometimes in veins and sometimes in bedded deposits associated with "intrusion" of diabase. The copper is most abundant when the diabase is thoroughly altered. He believes it has been leached by circulating ground water from the diabases. These diabases should correspond very closely to the Keweenawan. It is notable that the sulphides are mentioned, not native copper, and intrusives not effusives.

(3) The third question is as to the "explanation for the characteristics" of the deep waters high in chlorides. The authors of Monograph LII are not inclined to accept my suggestion that these characteristics are connate, that is original, "for all the essential kinds of conditions which produce the salt water of the ocean are present." (p. 544) "Chlorine is present," as they say, "in minute quantities in original igneous rocks and in nearly all surface waters. Its salts tend to remain in solution, while the salts of other acids are more largely precipitated. With a given amount of water, there seems likely to be, therefore, a progressive relative accumulation of chlorine salts. Such is the case in salt waters at the earth's surface, where a large factor in the accumulation is the lack of sufficient circulation to carry off and dilute the salt waters that are developing by evaporation. In deep underground waters there is essentially the same condition of stagnancy, and therefore we suggest progressive accumulation of soluble chlorine salts."

Is not evaporation an "essential kind of condition" for surface salt waters? The only thing that can replace it underground is rock hydration and the absorption of water into solid minerals. This may be a factor, but one would not expect it to be of much weight, especially when these salt waters occur in limestones and pure sandstones.

It is gratifying to notice that Van Hise realizes the importance of stagnant water. The more stagnant the water, the more largely

must it be connate. That the chemical composition of connate waters may be changed after burial, one can not deny, but the only way that one can suppose such stagnant connate waters could acquire the large percent of salts they often contain is to suppose that a small percentage of interstitial waters in the pores has leached a good part of a very small amount of chlorine from the fresh rock. A rock with a half percent pore space filled with water or say five ounces of water in a cubic foot would have about a sixth of a percent, of the weight of a cubic foot of rock. The segregation of enough chlorine to make this a strong solution of chlorides would be less than a tenth of a percent,—so small a quantity that no chemical work yet done, to be sure, is enough to prove that it may not have happened. Neither is there chemical or petrographic evidence, such as corroded apatite adduced to show that it has taken place. Stagnant waters would certainly retain strong traces of their original character, and I see no reason why my assumption that the chlorine is almost wholly connate does not better agree with the facts.

For in the first place, the term "progressive," as above used, must be understood as referring to time, not to space or distance from surface. If anything stands out from my mine water studies, it is the rather sharp change from fresh to salt. The fact that the salt water at the top has much more sodium in proportion to the strength than the stronger, deeper water, seems to show most surely that it is not by the increase of chlorine, first taking up sodium, then "when the sodium is taken care of by the chlorine," the calcium, but by a direct reaction of the calcium chloride waters, either with rocks that contain soda or surface waters containing sodium silicate or carbonate that these waters, intermediate in position, but not in composition, have been formed. I wish I had printed as a figure some diagrammatic tabulations of the composition of the waters in which this clearly comes out. The suggestion of Van Hise and Leith is, however, very interesting and important, if true,—that the percent of chlorine can be taken as an index of the degree of stagnation. In this, I should be inclined to agree myself.

With regard to the formation of copper (see especially page 558 of Monograph LII) we are agreed that the formation of the copper was but shortly after the formation of the beds in which it is found, and that the copper-bearing solutions were hot. I am inclined to dwell on the fact that they were unequally hot and think that they tended to throw down the copper in the hotter parts;

that the turning of calcium chloride into sodium chloride helps to throw out copper I do not doubt, but am inclined to emphasize the presence of trap rocks that help to make an alkaline solution. We agree that the water was "both juvenile and meteoric." I think the chlorine was also, and suggest that there may have been some concentration in desert pools, which lava streams may have helped to evaporate. We both are inclined to consider the effusive rather than the intrusive rocks as the source of copper. In that, we differ from the explanation of Volney Lewis of the New Jersey zeolites and the copper associated with them.

In 1911, I went down the Somerville mine, one of the deepest of the New Jersey mines, to the bottom. I saw no reason to believe that the formation of the copper was there different from that at Lake Superior. The occurrence is directly under and in the joints of an effusive lava sheet and seems to be where the water impregnating the sandstones and shales below (in which shales steam bubbles were formed by the lava) was hotter and more alkaline, being near the alkaline trap. The native copper appears to be an original ore as it is in Lake Superior and oxide and sulphide largely secondary. Fenner and Lewis have recently gathered numerous facts as to the paragenesis of the zeolites and the flow of lava on land and in lakes that entirely fit with what I have seen in Lake Superior. I wish I had read their works twenty years ago. But it must not be forgotten that the mineralizers or magmatic waters of a magma do not cease to exist, if, instead of being intruded, the molten lava reaches the surface, and there is no reason why the boron, found so often in borax lakes in volcanic arid regions, should not be efficient as a mineralizer, if buried under hot lava flows, even though it had seen day-light. The difficulties as to the source of boron raised by Lewis may thus be removed.

The "circulation" seems to me rather an imbibition or absorption with an ionic migration toward points where precipitation is going on. Long ago, de Lapparent called attention to the fact that the traps are alkaline and have a reducing action.

It would be foolish to deny that intrusives in many places have a large part in ore deposition. Intrusive traps occur at many places and at many ages, but the primary ore associated with them is generally chalcopyrite. Only in the formation of native copper does it seem as though it were needful for them to reach the surface so as to give the sulphur a chance to oxidize to sulphate and be carried in one direction, while the more readily re-

duced silver and copper, which have less affinity for oxygen than the sulphur, are reduced without it.

Native copper deposits, as I have pointed out, appear to be associated with certain former physiographic surface conditions.

The report of J. R. Finlay was made for purposes of taxation and this report is pretty closely confined to geology, but there is one sentence (p. 33) that I would challenge geologically, viz.: that "the copper district has been pretty thoroughly explored." According to the authors of Monograph LII and myself, the occurrence of copper has but little to do with the present surface, though there may have been some mainly pre-glacial, perhaps pre-Ordovician impoverishment connected with a surface not unlike the present. If, as I have suggested, certain lava flows evaporating certain pools in the desert tended to produce some concentration of copper, certain horizons must be regarded as more favorable than others. This might apply to the Kearsarge or Pewabic lodes. The Nonesuch horizon also shows heavy decomposition of basic rocks and there may have been copper dissolved in that connection, and while it shows signs of copper almost everywhere, it has been closely tested for copper but for a very few miles. The horizons of very few lodes have been explored for more than a small fraction of their distance.

Again, if I am right in thinking that the mineral crests or richest parts of the lodes are in the belt of middle waters, it is obvious that only explorations of lodes of something over 1,000 feet, on the average, is a fair test of their worthlessness.

Finally, when we remember that the surface of the range is largely covered by thirty to three hundred feet of drift, and that there is not the slightest reason, so far as I know, to suppose that there is any such connection between drift and the copper that the copper should be found mainly where the drift was thin; that the only way of testing drift covered regions at all is by diamond drills or shafts and that diamond drilling has been used not much over twenty years and is, at best, like probing for a needle in a haystack, with a long steel rod, it seems very unlikely that we have already pretty thoroughly explored and developed the best copper mines. It is quite likely that the cost of preliminary exploration may grow, but that, as fast as more copper is needed, more exploration will be done to find it and more will be found. I may say that I have some times, by request, refrained, in this report from reporting visible copper, so that the references to copper in the drill core, sections given in this report are not on

a uniform basis and cannot be used to determine the relative value of lodes.

Recent Explorations.

The geological and diamond drill exploration in the years 1909-1912 has been mainly in two districts. The one is from the Adventure and Lake Mines northeast. To some extent, drilling later than 1909 has been incorporated in Plates XIII and XIV. The formation is, no doubt, broken by many faults, but I know of no serious changes required in these or in Plate VIII, except (according to a theory I can not yet accept) in the neighborhood of the Lake lode.

The question as to the relation and direction of the Lake lode is still an open one. One theory is that it curves around, forming a synclinal and so continues with certain copper bearing belts of the South Lake. This would naturally imply a belt of at least some distance in Section 31, T. 51, R. 37 and 36, T. 51, R. 38, where the dips, instead of those everywhere else universally present through the Copper Range toward Lake Superior, would become southeastward. This is the theory which has been naturally attractive to the South Lake Mining Company and which is illustrated in the map accompanying their annual report for 1910. It is also favored in the Lake Mining Company report for 1911. One objection to it seems to be the apparent dip of the beds in Adventure drill hole 1, shown especially in the sandstone at 779. It will be remembered that that hole dips about 65° to the southeast, so that the bedding of the sandstone makes an angle of something from 40° to 70° against the direction of the hole. These observations would seem to agree with a northward dip such as we found at the Algomah and Lake properties, and would make it rather difficult, though not impossible to suppose that the dips were so suddenly reversed. The Algomah drilling shows northerly dips, I believe.

Another way to account for the apparent southward dips in Holes 4 and 6 of the South Lake is shown by studying the section of the Mass in Figure 52[1], these South Lake holes occupy a position relative to the formation between Mass d 5 and 1 of Figure 52. If there is a series of faults as therein indicated, throwing the southeastward side downward, it is quite easy to see that if one correlated horizons directly across, from one hole to the other, one could infer southward dips.

[1]In Fig. 52 the number to Hole 1 is carelessly omitted. It is the vertical hole just north of No. 2.

Which of the theories illustrated is the correct one, only further drilling, probably, can determine, and I may have been too much influenced in my feeling that there is no such fold, by the fact that no similar folds have heretofore been noticed.

The Contact, formerly Elm River Company, give in their report for 1912 an account of drilling in a heavy drift covered region, confirming, on the whole, the lines of Plate VIII, where it was a good deal guess work.

The second district is in the neighborhood of Calumet (Plate IX) where the Mayflower, Old Colony, Oneco, New Baltic and New Arcadian have been drilling. Many of the holes are not far from the lines of Conglomerate 8 of Plate IX, or, as it is often called, the St. Louis conglomerate. Its flat dip in the Torch Lake section (Fig. 38) becomes (according to the report of the mining company) steeper to 43° on the Old Colony and 50° on the Mayflower. The course of Conglomerate 8 may be rectified slightly.

The structure of the Torch Lake section, like the structure along the Keweenawan fault at the Lake and a number of other places, may be easily accounted for by the explanation given on the figure, i. e., by supposing that there was an uplift of the Lower Keweenawan accompanied by more or less normal faulting and that upon the uplifted and eroded edges of this Lower Keweenawan the Jacobsville sandstone was laid down, and that after this, disturbances still continued along the same line which here, and not infrequently elsewhere, took the shape of over-thrust faulting.

In Plate IX, there is an error whereby the base of the Eagle River group is placed at Conglomerate 17, just covering Marvine's groups b and c. Both Seaman and I agree that the more important change in the character of the trap is not at Conglomerate 17 but at Conglomerate 18 which in the Tamarack Mine is (394) feet above. Conglomerate 17, as the horizon of mining work at the Copper Falls, Arnold, Phoenix and Atlantic Mines, is, however, an economically important horizon. The boundary of the Eagle River group, as I have defined it, is at the top of Conglomerate 18 and should, therefore, be about 500 feet farther northwest in Plate IX.

With regard to Plate X, also, it should be noted that not only has the culture been revised, but the geology also, for which I, therefore, must now bear the responsibility rather than Dr. L. L. Hubbard. With regard to the densities of the rocks (pp. 66-97), it may be worth noting that the Calumet and Hecla Mining Company assume 12 cubic feet to a ton or 18 feet to a fathom

(6x6x6 = 216 feet) of ground of their conglomerate broken, and usually the same for the amygdaloid, which they say runs but little more—18.07.

To correct § 12 of Chapter I, (pp. 48 and 51), Leverett sent me the following interesting notes of his work.

In 1909, he found a well-defined beach on Centennial Hill in north part of Calumet which reaches 1303 feet A. T., and a lower one at 1,245 feet. Northwest of the Tamarack mine, are beaches at about 1,240, 1,220, 1,200, 1,170 and 1,135-40 feet. These beaches are all tilted in a north-northeast to south-southwest direction, the fall between these and the Quincy mine being about 3 feet per mile. The beach which is 1,135 feet at the Tamarack mine falls to about 1,080 feet west of the Quincy mine. The fall keeps about the same rate clear to the south shore of the old lake. The beach which is 1,303 feet A. T. on Centennial Hill falls to only 554 feet above Lake Superior on the north side of the Porcupine Mts., and 1,134 feet A. T. at Bruces Crossings or 169 feet in about 60 miles. It is doubtful if any beaches except the ones at 1,303 and 1,245 on Centennial Hill can be carried into the St. Croix outlet of Lake Duluth. It is also doubtful if any between 1,245 and 1,100 feet A. T. in the vicinity of Calumet belong to Lake Algonquin. The beaches at 1,220, 1200, 1,170 and 1,135 feet are suspected to pertain to a lake stage with outlet northwest into the basin of the Red River of the north which, at one time, held a large glacial lake —Lake Agassiz.

Regarding the mine waters, I should like to add an analysis of a salt water on the Baltic lode, where it was explored by the Atlantic mine, close to a fault. This was from a diamond drill on the 25th level, at a depth of 2,240 feet. The composition according to G. A. Koenig is

	$CaCl_2$	11.58	per cent
	$NaCl_2$	1.07	
	$MgCl_2$	0.06	
	SO_3	0.00	
that is:	Ca	41.7	per thousand
	Mg	.2	
	Na	4.2	
	Cl	81.0	
	Sum	127.1	

Na : Cl = .052

Ca : Cl = .515

The sodium is abnormally low.

Sp. Gr. at (20° C.) 68° F..1.1043. Temperature of the flow in the mine 62.6° F.

Absorbed gas 33.5 cc. per liter of which there was oxygen 6.27 present; nitrogen 93.73.

It is noteworthy, if this is correct, that while the gas is not the reducing inflammable gas which I had supposed associated with the rocks and the lower water, the oxygen is much less than in normal air, showing that if this gas is derived from air, it has been been exposed to reducing action. Occasionally, probably through some artesian circulation, the water is quite salt at a shallow depth. The dip of the rocks toward Lake Superior is such that one would expect such salt wells along the shore, if the strata were broken by fissures or joints, to give effect to the artesian pressure. An example seems to be met at Green, a hamlet west of Ontonagon, on the Lake shore. The Greenwood Lumber Company, in a well 100 feet deep, struck a water which was not a strong brine but in which the ratio of $NaCl:CaCl_2$ was, according to Dr. G. A. Koenig, as 0.06: 0.04. Another well, about 1,000 feet farther along the shore, was not quite so salt. This seems to indicate a mixture of a surface water with a little of a strong brine, like that of the Freda well, uprising from a depth or a fault (?)

The identification of the various zeolites is probably somewhat uncertain, especially as regards thomsonite. Inasmuch as I did not have the advantage of so thorough a treatment of the same, as is given in Winchell's "Optical Mineralogy," (pp. 394-410) very probably some of the minerals called thomsonite are other zeolites.

INDEX.

INDEX.

A.

Page

A a type of lava (See also amygdaloid conglomerate) . . . 69
Abeel, G. H., Jr., On Gogebic Range mine waters . . . 784, 785
Adamellose, defined . . . 72
Adams, F. D., cited . . . 79
Adventure Mine drill holes and section
    described . . . 574–587, 592
    referred to . . . 569, 570, 588, 594, 595, 598, 599, 946
Adventure lodes . . . 885
Agassiz, A., reference . . . 762, 763, 934
Agate
    Carnelian . . . 716
    occurrence in conglomerates . . . 630
    paragenesis of . . . 858, 860
Agate Harbor, reference . . . 200
Air drills, use of . . . 911
Akerose, defined . . . 72
Albany and Boston conglomerate . . . 409
    position of (See Allouez conglomerate) . . . 35
Albany and Boston Mine or section (See Franklin Junior) . . . 906
Albite twins of feldspar, extinctions of . . . 123, 630–754 passim
Algodonite, paragenesis of . . . 869
Algomah . . . 566, 865, 946
Allen, R. C., acknowledgment and reference . . . 13, 938
Allouez conglomerate 175–750 passim,—especially 436, 489, 490, 491, 493, 694, 714, 797, 799, 800, 802, 889
    correlations of . . . 175–750 passim
    position of . . . 35, 409
    termination of . . . 26
    See also Marvine's conglomerate.
Allouez, Father C. J., reference . . . 890, 891
Allouez Mine . . . 919, 923
Alteration (by water) . . . 94, 96
    of amygdaloids . . . 175–750 passim,—especially 791, 854
    of Calumet boulder . . . 87, 91
    of Keweenaw dikes . . . 91
Alumina
    in alteration . . . 89, 91, 94
    rock analyses . . . 99–119
    water analyses . . . 781–842
Amphibole . . . 62, 312, 662, 939
Amygdules . . . 175–750 passim
    agate . . . 628
    grain around . . . 149
    paragenesis of minerals in . . . 867
    pipe . . . 628, 650, 690, 713, 879
Amygdaloid
    alteration zones in . . . 854
    better defined in depths . . . 791
    favorable to copper . . . 829
    occurrence . . . 175–750 passim
    usage of term . . . 27, 51, 64
    See pumiceous amygdaloid

Amygdaloid conglomerate Page
defined ... 31
occurrence of ... 175–750 passim,—especially 363, 469
usage of term ... 34, 68, 69, 190
Amygdaloidal texture, usage of term ... 139
Analcite, analyses of ... 104, 849
occurrence of ... 252, 262, 684, 859
paragenesis of ... 859, 861, 862, 871
Analyses illustrating derivation of sedimentary from igneous rocks ... 115
Analyses illustrating kaolinitic alteration ... 117
Analyses of chloritic materials ... 114
Analyses of Calumet and Hecla boulder ... 89, 115, 116
Analyses of Duluth gabbro ... 101, 102
Analyses of feldspar ... 104, 658
Analyses of gabbro aplite ... 108
Analyses of greenstone ... 112
Analyses of Keweenawan rocks of Minnesota ... 100, 101
Analyses of Keweenawan sediments ... 118
Analyses of Lake Superior sandstones ... 118
Analyses of Lighthouse Point dike ... 99, 100
Analyses of lime melaphyre ... 113
Analyses of melaphyres ... 111
Analyses of minerals in Keweenawan basic rocks ... 103, 104
Analyses of Mt. Bohemia ophite ... 109
Analyses of Mt. Houghton quartz porphyry ... 106
Analyses of Nonesuch Shale by Dr. Gysander ... 30, 118
Analyses of Oligoclase gabbro ... 109
Analyses of olivine ... 104, 113
Analyses of ophites ... 516
Analyses of porphyrite flows ... 107
Analyses of pyroxenes ... 104
Analyses of sandstone ... 118, 629
Analyses of sodic melaphyres ... 110
Analyses of water ... 523, 570, 781–846 passim
Analyses, miscellaneous minerals, table of ... 105
Analyses, table of (See composition) ... 86
Analysis, methods of water ... 778, 835
Anamesite, usage of term ... 52
Ancient miners work of ... 889, 890, 899
Andose defined ... 72
Anhydrite, paragenesis of ... 861
Ankerite, paragenesis of ... 465, 467, 858, 861, 864
Anorthite ... 693
Anorthosite defined ... 71
Apatite ... 631, 638, 721
petrographic description ... 128
Aplite (See gabbro aplite).
Apophyllite
analysis of ... 104, 105
occurrence of ... 303, 858, 862
Apostle Islands sandstones ... 41, 940
Arcadian drill holes and section
described ... 430–456
referred to ... 200, 274, 275, 298, 301, 304, 320, 323, 324, 325, 379, 381, 407, 419, 420, 421, 422, 431, 437, 461, 463, 467, 563, 669
Arcadian lode, reference ... 371, 448, 464, 467, 486, 561, 905
Arlington (Schuyler) Mine, New Jersey, copper at ... 876
Arnold Mine section described ... 259, 262
Arsenic in copper (See Mohawkite) ... 830, 868–871
Arsenides in Bolivia ... 879
Artesian flows ... 570, 759, 838–847, 949
Ash, volcanic, occurrence of ... 668, 690, 691, 694, 739, 755
Ashbed ... 34, 175–750 passim,—especially, 670
definition of ... 31
(See Ashbed group and Mesnard lode.)

Page
Ashbed (conglomerate), description of....35, 68
occurrence (See Marvine's conglomerate 17).... 17, 262
Ashbed group, characteristics of....29, 35, 138
composition of traps of....110, 111, 114
exploration on, amount of....172, 173
occurrence of....261, 409, 436, 548, 551, 559, 565, 605. 624–625, 629, 652 and passim to 692
specimens from.... 142
thickness of....37, 310
Ashbed mine, location of....35, 911
Atlantic mine section 16 crosscut of....459, 494, 563
Atlantic Mine, methods of mining....920, 921
section at....491–494
temperature in....760, 949
water in....829, 948, 949
Augite
composition of....76, 103, 104
decomposition to chlorite....123, 229
decomposition to hornblende....123, 230
grain of....146, 175–750 passim
porphyrite hiatal....732, 733
petrographic description of.... 122
prismatic form of....123, 393, 702
sheaf like.... 639
Augite porphyrite....56, 392
Aurora Mine, water of....782, 783
Auvergnase, occurrence of.... 518
Auvergnose, defined 72–73, 79, 518
Aztec Mine (South Lake), reference....566, 574
Azurite, occurrence of.... 861

B.

Backbone greenstone.... 739
Ball steam stamps, use of.... 906
Bad River gabbro, appearance of....60, 627
grain of.... 129
Baltic conglomerate....34, 225, 474, 483, 498, 499, 522, 527, 544, 564
See also Marvine's conglomerate 3.
Baltic lode,
dip of beds on.... 23
location of.... 48
mining operations on.... 917
occurrence of....473, 497, 498, 499, 505, 522, 523, 544, 564
paragenesis of minerals in....826, 828, 831
salt water in....828, 829, 948
Baltic Mine, methods in....922, 923
Baltic Mine section.... 498
Baltic sandstone....495, 499
See Marvine's conglomerate 5
Bare Hill, felsite at.... 755
Barite, paragenesis of....803, 858, 860, 861, 868, 879, 880
Barrell, J., reference.... 32
Barrel work (copper).... 902
Basalt, usage of term.... 27, 52
Basalt porphyry, usage of term.... 64
Bastite, see Olivine alteration products of.
Bathalite, a possible cause of faults.... 21
Baveno plagioclase twins....679, 683
Bay City, geothermal gradient at.... 768
Bayley, W. S., reference....56, 59, 71, 781, 933
Beaches, altitudes of....49, 948
Becke, F., reference.... 76, 120
B. Shaft of Minnesota Mine....610, 611, 825

Page
Beerbachose, defined 72
Bell, J. M., reference 850
Belt Mine (See Lake Mining).
Belt formation, copper in 942
Bismuth, characteristic of "Western copper" 863
Black Hills, part of Calumet Mine
copper and silver in 810, 863
Black River, section
abstract of 624–627
reference to 35, 37, 39, 40
Blake Point, Isle Royale, formerly "Greenstone" 692
Blandy, J. F., reference 935
Bohemia conglomerate .... 33, 34, 175–750 passim,—especially 189, 190, 243
See Marvine's conglomerate 8.
Bohemian Range group,
distribution of 172, 173, 450, 456, 459, 463, 485, 614, 625, 627, 628, 748, 756
thickness of 33, 310
Boiling point of salt mine water 795
Bolivia, native copper in 874, 879
Bolson, Keweenaw rocks formed in a 585, 940
Bornite, occurrence of 629
Boss, C. M., reference 934
Boston Creek 487
Bowen, N. L., acknowledgment 79
Bowlingite, see Olivine, alteration products of
Brady, S., reference 604, 609
Branch vein, see Rockland
Brauns, R., reference 938
Breakfast Lake, section north from.
See Clark Montreal section.
Breccia, definition of 31, 32
fault .... 175–750 passim
Brick clay 526, 567, 597
Britannare, defined 71
Brogger, W. C., reference 76
Bromine,
occurrence of 788, 793–796, 805, 807–808, 813–815, 817, 818, 823, 830, 831, 838
Brooks, T. B., reference 894
Brotocrystals 80, 668, 681, 685, 691, 716, 739, 748, 755
Broughton, S. H., reference 610
Brucite, occurrence 379
Brun, A., reference 45
Bunsen,
normal basaltic magma,
composition of 65, 75, 76, 81, 102
grain of 146
normal trachytic magma,
composition of 75, 76
Burrage, A. C., acknowledgment 15
reference 430
Burrall, F. P., analyses by 106, 107
reference 658, 659, 660
Burt, W. A., reference 51, 52, 893
Buthiatrephis 525
Butler lode, occurrence of 567, 611, 612
Byerly, W. E., reference 156, 158, 768, 769, 771
Bytownite, porphyritic 644

C.

Cables, use of in mines 912
Calcite,
occurrence of .... 175–750 passim,—especially 552, 607, 641, 723, 754, 767, 826, 831
855, 877
paragenesis of 295, 615, 617, 858, 859, 860
petrographic description of 126

Page
Calcium,
in alterations....94, 776
in rock analyses....99-119
in water analyses....781-891
Calcium chloride in rock....805, 806
wide spread occurrence of in waters 841
See analyses.
Caldwell drill holes, described....320-324
drill holes referred to....325, 326, 327
Caledonia Bluff.... 604
Caledonia conglomerate....567, 576, 580, 588, 593, 612
See Marvine's conglomerate 8.
Calico lodes....493, 556, 557, 565, 569, 590, 610
See Houghton conglomerate.
Calumet,....23, 947
subdivisions at.... 39
thickness of Keweenawan at.... 37
Calumet amygdaloid,
occurrence of....175-750 passim,—especially 252, 411, 423, 705
Calumet conglomerate, composition of....68, 89, 93, 118, 361, 362
composition of water in....802-804, 807-811
decomposed boulders in....87-91, 353, 361, 364, 365, 864
discovery of.... 908
occurrence of....181, 196, 208, 251, 252, 258, 264, 267, 314, 361, 365, 367, 411, 423, 440, 444, 558, 703, 715
richness of....43, 48, 810, 811, 850, 889
Calumet and Hecla Mine,
methods in....908, 918, 920, 923, 924, 926, 927
Calumet and Hecla Mine, temperature observations at.... 762
Calumet and Hecla Mining Company,
drill holes referred to....298, 419, 442, 444, 839
drill holes on section 18 described....328-333
near Kearsarge lode described....366-370
water of shaft 21 (Kearsarge) referred to.... 171
Cambrian age of Keweenawan....940, 941
Cameron, F. K., reference.... 850
Camptonose, defined.... 73
Canadare, defined.... 71
Canadian Geological Survey.... 756
Canadian Mining Institute, proceedings cited.... 784
Cape d'Or, copper at.... 878
Capen vein, horizon of....464, 465
Card Point, Isle Royale, greenstone at.... 692
Carnahan, A. L., reference.... 937
Carp Lake.
See also Little Carp Lake.
Cascade River, porphyry near.... 624
Cass, Lewis, reference.... 892
Castile Mine, base of Keweenawan at.... 628
Celestite, occurrence of.... 803
Centennial Mine,
natrolite.... 859
section at.... 365
shafts at.... 919
water at....817, 818-820
Central Mine,
Mohawkite in.... 869
temperature in.... 760, 761
vein.... 855
Central Mine cross section,
described....264-309
specimens from.... 142
Central Mine, drill holes referred to....188, 193, 196, 198, 200, 210, 217, 219, 220, 236, 237, 238, 239, 240, 249, 256, 275, 324, 386, 419, 442, 444, 715, 729, 732, 756

Page
Central (Mine) group 629
beginning of 34, 409, 436
end of 34, 450, 463
per cent of sediment in 455
specimens from 142
thickness of 35, 310, 455, 456
Chalcedony, occurrence of 378, 720, 731, 753, 858, 859, 860
Chalcocite, occurrence of 629, 756, 831, 861
Chalcopyrite, occurrence of 228, 629, 756, 876
paragenesis of 861, 868, 879
Challenge exploration cross section,
described 505–524
referred to 170, 527, 538
salt water at 833–7
Chamberlin, R. T., on gases 45, 418, 842, 862–3
Chamberlin, T. C., reference 27, 762, 763, 768
Chambers in mining 911
Champion Copper Mine, geological conditions at 505, 522
minerals in 860, 870
mining methods at 918, 922
salt water in 829, 831, 832
temperatures in 760, 761
Champion Iron Mine,
temperature in 760, 761
water in 787
Champion Lode in Evergreen Bluff 567
Chemical classification of rocks 73
Chili, copper in 776
Chippewa felsite,
occurrence of 33, 409, 565, 606, 622, 625, 626, 689
Chippewa lobe 526
Chlorastrolite,
analyses of 104
paragenesis of 93, 94, 125, 858
Chlorine,
See mine water analyses of.
Also endothermic reactions.
Chlorite . . . . . 175–750 passim,—especially 275, 294, 295, 297, 363, 451, 684, 708, 725, 844, 853
analyses of 83, 114
occurrence of 63, 83, 94–96
paragenesis 93, 615, 860, 866, 867
tufted 684
Chloritoid 788
Chrysocolla, paragenesis of 861, 865
Chutes, see shoots.
Chynoweth, Jas. S., acknowledgment and reference 15, 371, 527, 859
Chynoweth, S., acknowledgment 527, 533
Clark, Wesley, reference 262
Clark-Montreal section, described 174–190
referred to 193, 194-199, 251, 254, 886
Clasolite, occurrence . . . . . 175–750 passim
definition of 31, 47
Classification, of rocks quantitative 71
Clay and kaolin 710
petrographic descriptions 128
See also fluccan and brick clay.
Cliff Mine,
salt water in 774
section 314
work at 896, 899
Clinker bed, definition of 31
Cobb, M. A., analysis by 787
Cobrizos 880

Page
Colby Mine, water in 784
Cole's Creek, sandstone on 487
Collen, M., on belt formation 942
Compositions (chemical) 57–119
of Nonesuch shale 30
of traps 26, 27
See analyses.
Compass, variation of, near lodes 910
Conductivity,
of copper 870
of rocks 765, 766
of snow 772
Conglomerate Bay 651
Conglomerate Mine, temperature in 760
Conglomerates, position of various 35, 37, 39, 482, 753
See also list under Marvine's numbers and synonyms there given.
Connate waters,
See waters, mine.
Connecticut Mining Property, location of 259
Consanguinity of rocks, defined 77, 78
Contact effects 72, 109, 229, 416, 939
Contact Copper Company, reference 527, 530, 947
See Elm River.
Cook, Newell, analyses by 108, 109, 110
Cookose, defined 73
Cooling, effect on grain 145–169
earth temperature gradient 766–770
Cooper, J. B., acknowledgment 15, 93
reference 869
Cooper, J. R., reference 916
Cooper, W. F., reference 524
Copper,
cost of 918
crystallization of 811, 855, 857
slow 767
formation of 43, 83–90, 777, 847, 872, 873, 880, 885
distribution of ..... 41, 487, 497, 799, 813, 850, 873 and passim
mass 888, 892, 899, 900
no 790
occurrence of . . 42, 175–750 passim,—especially 398, 418, 444, 461, 473, 552, 577, 607, 616, 639, 658, 684, 687, 700, 706, 711, 712, 723, 724, 735, 738, 767
occurrence 810, 813, 824, 831, 851, 852, 853, 857, 874, 875, 876, 888, 922
in drift 48, 904
in mine waters 42, 778, 792–795, 803, 807, 814, 815, 818, 819, 823
in shale 421, 581
origin of 872, 873, 944
epigenetic 880, 885
synegenetic 880, 885
paragenesis of ..... 175–750 passim, 561, 617, 858, 860, 861
See also prehnite, datolite and calcite.
percentage in lava or lodes 175, 778, 813
in mine waters 793–796
petrographic description of 127
production of 923
replacement by 42
residual nuggets of 474, 828
sulphide derivation 870
tempering 857
water associated with 809, 822
Copper Crown Mine, work at 622
Copper cutters 900
Copper Falls adit 259, 652
"Copper Handbook," cited 409

Page
Copper Harbor conglomerate....605, 625, 627
base of.... 332
use of term.... 37–39
See also Great and Outer Conglomerate.
Copper Harbor, vein at.... 896
"Copper Mines of Lake Superior," cited.... 409
Copper Point, Mamainse, porphyritic bed at.... 738
Corey, G. W., reference....337–348, 936
Cornish Stamp, use of....902, 903
Corocoro, Bolivia, copper mines at....879, 884
Courtis, W. M., on Silver islet mine water....774, 788
Credner, H., reference.... 53, 68
Cretaceous peneplain, referred to....48, 940
Crustification, absence of.... 884
Crystallinity of rocks.... 129
Crystallization, power of, defined.... 149
Cumberland Point.... 652
Cypricardites at Limestone Mt.... 525
Cyrtodonta at Limestone Mt.... 525
Cuneamya at Limestone Mt.... 525
Cuprite, paragenesis of.... 861
Curtis, H. L., reference.... 771

D.

Dacotah Heights Company, drilling by....486, 488
Daly, R. A., reference....77, 78
Darapsky, L., on Chilean mine waters....882, 933
Datolite.... 42
occurrence of....214, 237, 239, 262, 301, 304, 306, 309, 376, 379, 405, 471, 556, 561, 591, 628, 667, 675, 712, 720
paragenesis of....858, 861, 862
petrographic description of....127, 561
precipitating copper.... 849
Davis, C. A., reference.... 936
Delaware Mine, cross section at.... 257
temperature in.... 760
water in.... 802
Delessite....175–750 passim,—especially 688
paragenesis of....858, 860
See chlorite.
Dengler, T., reference....492, 494
Dennis, M., acknowledgment.... 15
Density, see specific gravity.
Denton, F. W., acknowledgment.... 15
referred to....407, 546, 625, 832
Deposition, dips of.... 680
Devon conglomerate.... 622
Diabase, usage of term....52, 61, 63
analyses....99, 100, 116, 117
decomposition.... 91
occurrence....627, 628, 756
Diamond drill exploration....910, 945
Differentiation,
magmatic....658, 659, 739
wet and dry....81, 82, 79–83
See mineralizers.
Diffusivity, effect of varying on grain....155, 167
in Keweenawan rocks....Ch. VI, 765, 766
of snow.... 772
Dikes,
occurrence of....784, 785
Dip of beds....23, 175–750 passim, 790, 799
at Medora shaft.... 802

Page
Dip needle, deflection of ... 910
Doelter, C., reference ... 150, 154
Dolerite, usage of term ... 27, 52, 66
Dolerite porphyry, usage of term ... 64
Doleritic melaphyre, definition of ... 27
occurrence of (See doleritic texture).
Doleritic ophite ... 175-750 passim,—especially 446
Doleritic texture,
cause of ... 83, 134-6, 183, 445
copper in ... 86, 221, 222, 234, 419, 452, 510
grain in ... 136-7, 185, 201, 214, 216, 246, 253, 303, 306, 307, 310, 356, 360, 368, 420, 424, 530
Doleritic texture,
occurrence of ... 183, 199, 228, 240, 244, 254, 305-6, 368, 444, 466, 592, 645, 655, 708, 721, 723, 750, 853, 939
parallel to bedding ... 570
rhyocrystals in ... 246
usage of term ... 28, 66, 134, 135
See also chlorite.
See also druses.
Dolomite, paragenesis of ... 860
Domeykite, paragenesis of ... 861, 868, 879
Doney, J., reference ... 799
Dorchester Mining Company ... 906
Douglas, E. Fenner, acknowledgment ... 15
Douglas, James, reference ... 933
Douglas Houghton Falls, occurrence of ... 22
Drainage, Pre-glacial ... 527, 564, 588, 604
Drift, thickness of.
See drainage pre-glacial and overburden.
Drill holes,
crookedness of ... 520, 534, 586
observations ... 175-750
temperature in ... 762, 763
Drum, types of, in mining ... 912, 927
Druses ... 277-279, 291-297, 371, 690, 708, 725
See doleritic textures.
Duluth gabbro, analyses of ... 101, 102
Duparc, Louis, reference ... 934
Durkee, F. W., analysis by ... 798

E.

Eagle River, thickness of Great Copper Harbor Conglomerate at ... 39
Eagle River group ... 629, 630
occurrence of ... 37, 548, 573, 605, etc.
thickness of ... 310
Eagle River section,
described ... 311-313
referred to ... 261, 262, 311, 332, 640, 645, 647, 657, 658, 661, 664, 678, 681, 691
Eastern Sandstone,
See Jacobsville sandstone.
Edwards, R. M., acknowledgment ... 15
reference ... 762
Effusive and instrusive rocks distinguished ... 60, 62, 63, 129, 135, 168, 939
Egleston, T., reference ... 887, 931
Ellipsoidal greenstones ... 399
Elm River Company, see contact.
Elm River drill holes, described ... 530-535
Elm River drill holes, referred to ... 538, 561, 563
Elm River section, abstract of ... 528
Emerson, L. E., reference ... 260, 262, 593
on salt water ... 774
Empire drill hole, described ... 192-200

Page
Empire drill holes, referred to..............170, 183, 208, 210, 250, 252, 253, 254, 255, 256
Empire section..191-200
Endothermic reactions..................................764, 765, 770
Eocrysts..133, 678
See hiatal texture.
Epidote,
copper in..530, 584
crystals in..280-291, 669
distribution of......188-750 passim,—especially 227, 270, 293, 296, 379, 465, 467, 552, 826
paragenesis of.....................85-86, 513, 552, 615, 617, 858, 860, 864, 866
petrographic description of.................................... 127
zoisitic.. 457
Eutectic..72-75, 79-81, 102, 103
dry.. 73
Evans tables.. 929
Evergreen Bluffs.. 565
Evergreen Shaft..................................567, 568, 593, 594, 611
Exner, Sigm., reference.. 120
Explosives.. 907

F.

Faulting near Portage Lake.. 486
Faults....21, 22, 23, 24, 173, 175-750 passim,—especially 260, 262, 437, 469, 475, 566, 613, 623, 629, 646, 670, 688, 707, 725, 740, 756, 791
strike..595, 626
upheaval.. 573
See slides.
See fractures.
See grain, crack effect on grain.
Fay, H. B., acknowledgment to.. 527
Feldspars,
analysis of..104,658
in altered boulders..87, 90, 353
petrographic description of....................................123, 175-750 passim
pink secondary..308, 361
primary..175-750 passim
seriate porphyritic.. 643
zonar extinctions of.. 724
Feldspathic melaphyre..175-750 passim
See also plagioclase.
Felsite.
distribution of..172, 173, 565, 573, 755
usage of term.. 55, 71
Felsite breccia, defined.. 68
origin of.. 68
Felsite tuff..399, 401
See Mesnard epidote, and Ashbed.
Fenner, C. N., reference..32, 878, 937, 944
Fernekes, G., reference..42, 43, 757, 766, 778, 780, 781, 786, 790, 792, 793, 797, 816, 847, 848, 866
Finlay, J. R., reference..938, 945
First Adventure lode.. 583
First Mountain.. 885
Fischer well.. 841
Fisher, J., Jr., reference..98, 790, 804
Fissure veins.. 909
Flemington Mine.. 876
Float copper, distribution of.. 48
Floating lever..927, 928
Flow sheet.. 930
Fluccan, described..21, 47, 556
occurrence of....175-750 passim,—especially 270, 449, 455, 552, 554, 555, 556, 560, 616, 619, 646
paragenesis of.. 858

Flourite — Page
bluish ... 754, 755
petrographic description ... 128
with calcite ... 754
Fontainbleau calcite pseudomorphs ... 604
Forbes, D. C., reference ... 880
Ford, Wm. E., letter of ... 126
Forest Conglomerate ... 614, 825, 826
Formis, A., acknowledgment ... 15
reference ... 782
Fort Wilkins, temperature at ... 896
Foster & Whitney, reference ... 29, 52, 53, 96, 629, 758, 894, 897, 900
Foster Mass Amygdaloid ... 464
Fractures, see faults.
Franklin, B., reference ... 891
Franklin Junior drill hole, described ... 407–422
referred to ... 200, 218, 219, 273, 298, 324, 366, 413, 414, 420, 435, 440, 441, 444, 445
Franklin Jr. Mine ... 406, 407, 437, 688, 691, 789, 797, 801, 802, 844
Frapwell, A. P., reference ... 800, 825
Freda ... 838
Freda sandstones, described ... 40
referred to ... 406, 456, 485, 487, 604, 622, 625, 627, 630, 840
Frontenac drill hole ... 253
described ... 253–256
See Manitou.
Frue automatic tramway ... 926
Fuller, M. L., reference ... 565

G.

Gabbro (Bad River) ... 627
character of occurrence of ... 33, 129
of Mt. Bohemia ... 108, 109, 229
of Porcupine Mts ... 624
Gabbro aplite,
analyses of ... 108
definition of ... 40. 56, 59, 60
occurrence of ... 60, 82, 231
texture of ... 141
Gabbro, definition of ... 27, 134, 135
Gabbro, usage of term ... 60, 63, 135
Gabbro intrusion ... 72, 624, 627
pegmatites ... 939
sill ... 627
See Mt. Bohemia, Porcupine Mt., Bad River.
Gases ... 843
effect of ... 146, 231, 949
in mine waters ... 788, 842
in rock ... 842, 855
Germania Mine ... 783
Giraffe vein, usage of term ... 201
Glacial action, described ... 48, 824
deposits ... 569, 888, 918
phenomena ... 525, 540
Glass, brown ... 718, 719, 726, 753
conchoidal, fragments of ... 739
Glen Ridge Mine ... 876
Globe ... 505, 832, 918, 924
Glomeroporphyrite ... 175–750 passim,—especially 303, 306, 307, 377–379, 391, 422, 424, 473, 488, 612, 729
definition of ... 27, 137
texture of ... 35, 64
marginal ... 240
Glomeroporphyritic texture,
occurrence ... 549, 559, 587
usage of term ... 137

Page
Goldthwaite, J. W., reference.......... 936
Goodale, S. G., acknowledgment..........527, 932
Gordon, W. C., reference..........39, 565, 625
Gouge.......... 291, 372
See fluccan.
Grain of rocks, effect of crack on.......... 149
inaccuracy in observing..........154, 201
indicating faults.......... 709
irregular, explanation of.......... 634
observations on..........176–760 passim
variations in.......... 576
See also ophitic and doleritic texture.
Grand Portage amygdaloid..........448, 905
Granophyric texture.
See graphic texture.
Grant, U. S., reference.......... 56, 59
Graphic texture, described.......... 140
See micropegmatite and granophyric.
Grayling.......... 768
Great (Copper Harbor) Conglomerate..........548, 565, 573, 624
composition of.......... 67
described.......... 39
position of..........37, 174, 328, 605, 625, 627
thickness..........39, 310
Green.......... 840
Greenland.......... 574
Greenstone bluff.......... 896
Greenstone.
analyses of.......... 112
contact.
upper.......... 245
lower.......... 247
see "slide" under and Allouez Conglomerate.
differentiation in..........135, 246
doleritic texture in..........135, 201, 246
effusive character of textures in..........135, 939
extent of..........22, 456, 490, 491
grain of..........137, 170
occurrence of..........262, 409, 436, 552, 559, 561, 629, 652, 678, 688, 689, 691, 692, 693, 739
ophitic texture in.......... 133
petrography of..........312, 692–694
porphyritic heatal plagioclase in..........201, 246, 692–694
thickness of..........32, 174, 245, 263
usage of term as proper name..........52–54, 939
Greenstone, "slide" under.......... 26
See Allouez conglomerate.
specific gravity of..........99, 112
Greenwood Lumber Company..........840, 949
Grierson, E. S., acknowledgment.......... 15
reference..........810, 819, 820
Grout, F. F., reference..........78, 104
Grunerite.......... 788
Gypsum.......... 831
paragenesis of..........858, 861, 868, 879, 880
with copper.......... 884
Gysander, C. R., analysis by.......... 118

H.

Hahn, H. C., reference.......... 844
Hahn, C. Otto, reference.......... 883
Haight, C. M., reference..........604, 612
Haire, Norman W., acknowledgment.......... 15
Hall, J., reference.......... 762

Page
Hancock, dip of beds at 23
quarry near 456
Hancock lode 491
Hancock Mine 486, 487
Hancock West Conglomerate 546, 550, 551, 661, 669
See Marvine's comglomerate 17.
Harker, A., reference 63, 77, 154
Harmony Iron Company 783
Hartman, W. F., acknowledgment 15
Hauy, R., reference 883
Hawes, G. W., reference 94
Hays Point 896
Heath, G. L., analyses by 15, 89, 802, 803
Hematite 600
Hematite plates . . . . . 175–750 passim
paragenesis of 860, 864
Henry, Alexander, reference 891
Heron Lakes, geology near 525
Herrick, C. L., reference 55
Hessose, defined 72
See melaphyre.
Hiatal texture 138
occurrence of 241, 434, 678, 733
See also Huginnin.
porphyrite, Kearsarge amygdaloid, eocrystals and rhyocrystals.
Hilton 574
Hobbs, W. H., reference 22, 59, 76
Hohl, C. D., reference 820
Hoisting 926
Holm, M. L., reference 824, 833, 835, 837, 841, 844
Honnold, W. L., reference 485, 524
Hooper, Geo., acknowledgment 15
Hore, R. E., reference 621, 810, 937, 938
Horse whim 901
Hotchkiss, W. O., acknowledgment 15
Houghton 917
Houghton, dip of beds at 23
Houghton, Douglass, reference 37, 51, 53, 892, 893
Houghton, Jacob, reference 889
Houghton Conglomerate . . . 175–750 passim,—especially 188, 192, 193, 249, 257, 258, 264, 363, 410, 437, 493, 554, 558, 559, 698, 715
position of 35
Hubbard, B., reference 51, 52, 53
Hubbard, L. L., acknowledgment 15
reference 31, 33, 56, 107, 174, 229, 261, 262, 263, 265, 268, 297, 407, 444, 451, 464, 486, 491, 505, 546, 565, 691, 767, 825, 855, 859, 933, 934, 935,
Huginnin Cove 738
Huginnin Creek 738
Huginnin porphyrite 56, 729, 738, 739, 748, 753
Hulst, H. R., reference 787
Hungarare, defined 73
Hunt, T. Sterry, experiments by 84, 852, 867
Huntington, E., reference 32
Hurlbert, E. J., reference 487, 908
Hurley Mine 783
Huron Mine 824
Huron Mining Company 905
Huronian rocks 18
Hyalopilitic texture, usage of term 139
Hydration 84, 852

I.

Iceland spar.
See calcite.
Page
Iddings, J. P., reference....76, 77, 78
Iddingsite, see Olivine, alteration products of.
Illinois (steamer)....906
Indiana....565
Indians....890
Intrusives, composition of....100, 101, 108
contact effects of....229–231, 939
occurrence of....374, 393, 400, 565, 580, 624, 628, 740, 756, 774, 788
textures characteristic of....61, 62, 63, 171, 646, 939
See also gabbro, aplite, diabase, porphyry.
Ions migration in copper formation....43, 864
Iron country mine waters....780
Iron oxide,
in alterations....94
in rock analyses....99–119
in water analyses....781–841
Iron oxide, as rock constituents....175–750 passim
See Olivine, alteration product of.
extra abundant in certain melaphyres....601, 742, 749, 750
Ironwood, salt water at....628
Irving, J. D., reference....39
Irving, R. D., ...39, 41, 54, 55, 173, 624, 625, 686, 933
Ishpeming Mine water....782
Island Mine Conglomerate....651, 652, 653, 661
Isle Royale, section on,
described....629–755
referred to....29, 35, 548, 939
Isle Royale Consolidated Mining Company section.
described....459–485
referred to....381, 382
specimens from....142
Isle Royale Consolidated Mine, mine water....822
Isle Royale lode.
See Arcadian.
Isle Royale Mill....929
Isle Royale Mine....458, 524, 859, 907
Isle Royale—Arcadian....371

J.

Jackson, C. T.,
analyses by....103, 105
reference....52, 96, 758, 894
temperature observations....759
Jackson, J. F., reference....935
Jacksonite, referred to....126
Jacobsville sandstone....41, 401, 406, 476, 485, 524, 544, 572, 603, 628
Jasper....52, 558
Jefferson, M. S. W., reference....936
Jigs, use of....914
Johnson Creek Conglomerate....527, 546, 554
Johnston, W. H., reference....787
Julien, A. A., reference....53

K.

Kaolinite, paragenesis of....860
Kaolinitic alteration....91, 117, 785
Karlsbad twins, occurrence....89, 90, 123, 630–754, passim
Kawau Island Copper Mine....870
Kearsarge amygdaloid and conglomerate,
occurrence....175–750 passim, especially 184, 199, 215, 235, 255, 257, 259, 340, 367, 414, 415, 416, 418, 429, 431, 443, 917

Page
Kearsarge conglomerate,
occurrence of....26, 35, 264, 269, 297, 412, 439, 441, 442, 556, 558, 714, 715, 719, 728
Kearsarge lode 810
copper and water in....810–822, 885
correlation with....557, 565, 726, 727
extent of....25, 493, 945
Kearsarge lode (amydgaloid)
hiatal crystals in foot wall of....138, 257
mining upon.... 919
origin of 315
phenocrysts in....224, 225, 273, 274, 427, 428
Keweenaw fault, The....21, 406, 485, 573, 888
Keweenaw lobe.... 526
Keweenaw Point, thickness of beds at end of.... 39
thickness of Outer Conglomerate.... 39
Keweenawan rocks,
age of 940
analyses of minerals in....103, 104
consanguineous relationships of.... 78
occurrence of.... 45
quantitative classification of.... 70
specific gravity of....97, 98, 99
thickness of....174, 310, 558, 559
Keweenawan rocks of Minnesota, analyses of....100, 101
Keweenawan sediments
amount of in Central Group.... 34
composition of....32, 40, 67, 118
signs of subaerial origin....42, 67, 479, 541, 646, 721, 753, 845
of lake origin....32, 578, 585, 620, 879
of marine origin 879
Keweenawan series, Lower.
age of.... 939
base of.... 630
Upper relation of....173, 623, 625, 630, 756, 940, 941
Keweenaw type of rocks, Osann's.... 518
Keeweenawite.... 813
paragenesis of.... 869
Kedzie, F. S., analysis by.... 839
Kelly, W., on Vulcan Mine waters.... 780
Kemp, J. F., reference....57, 775
Keratophyre, defined.... 71
Keewatin center.... 526
Keweenaw Copper Company, water from Medora shaft of.... 802
See Mandan cross section.
Keyes, C. R., reference.... 775
Kilauose, defined.... 73
King Philip Mine,
geology near.... 564
waters in....824, 837
Kingston conglomerate (same as Kearsarge).... 270
Kirschbraum, L., analyses by....108, 109, 110
Knopf, Adolph, reference.... 937
Knowlton vein, occurrence of....567, 574, 576, 588, 591, 593
Koch, A. A., reference....52, 53, 810, 821
Koenig, G. A., reference....790, 792, 838, 859, 933, 934, 935
Königsberger, J.... 764

L.

Labrador center.... 526
Labradorite....312, 515, 630–750 passim, especially 703
paragenesis of.... 849, 860
Labradorite porphyrite, usage of term.... 64
occurrence of.... 28
Labradorose, defined.... 71

Page
Lac la belle conglomerate ... 225
See conglomerate 3, Baltic conglomerate.
Lake Agassiz, connection with post glacial beaches ... 948
Lake Algonquin, reference to beaches of ... 50, 948
Lake Brand of copper ... 767, 916
silver in ... 860, 863
Lake Duluth, reference to beaches ... 49, 948
Lake Linden ... 839
Lake Mining Company section,
described ... 566–574
referred to ... 48, 573, 588, 593, 594, 595, 840, 946
Lake Nipissing, reference to beaches ... 50
Lake Richie ... 692
Lake Shore traps, distribution of ... 39, 173, 605, 625, 627
thickness of ... 174, 310, 623, 625
Lake Superior, size of ... 18
Lake Superior, a basin ... 15
Lake Superior sandstones ... 630
analyses of ... 118
See also Jacobsville and Freda sandstones.
Lane, A. C., work of ... 56, 762, 935, 937, 938
de Lapparent, A., rêference ... 944
Larsen, E. S ... 767
La Salle Mining Co.,
mine water of ... 821, 822
sections on ... 319
Laumontite ... 849
occurrence of ... 175–759 passim, especially 599, 677, 706, 811
paragenesis of ... 849, 858, 860, 864, 865
petrographic description of ... 125
unfavorable to copper ... 849
Laspeyres, H., reference ... 883
Lawson, A. C., reference ... 23, 933
Lawton, C. B., acknowledgment ... 15
Lawton, C. D., reference, Com. of Min. Stats ... 257, 261, 267, 487
Lebachose, defined ... 71
Ledouxite, paragenesis of ... 869
Leith, C. K., reference ... 13, 32, 938
Leoben, M. Lazarevic, reference ... 938
Leopard sandstones ... 456
Leucoxene ... 662
Levels, distance apart in mining ... 910
Leverett, F., on glacial geology ... 760, 948
Lévy, Michel A., reference ... 76, 130
Lewis, J. Volney, reference ... 737, 874, 877, 884, 885, 936, 938, 944
Lighthouse Point dike, analysis of ... 99, 100
Lime, effect of alteration on.
See also composition.
Lime melaphyre, analyses of ... 113
See ophite.
Limestone Mountain, palaeozoic strata at ... 22, 485, 521, 524, 824
Limonite, paragenesis of ... 861
Linceo, G ... 767, 860
Lindgren, Waldemar, reference ... 938
Liparase, defined ... 71
Little Carp Lake, elevation of ... 624
Little Montreal River, felsites of ... 190, 755
Locke Point, Minong trap at ... 716
Lone rock,
no dike in Upper Keweenawan near ... 39, 173, 623
Longyear, J. M., reference ... 624, 849
Loring, Thacher, reference ... 374
Los Banitos, salt waters of ... 882

M.

Page
Mabbs, John, reference 907
Mackie, William, reference 874
Magdeburgose, defined 71
Magnesia 816
in alterations 84–94
in rock analyses 99–119
in water analyses 781–841, 844, 853
See also chlorite, delessite.
Magnetite, paragenesis of 860
Malachite, paragenesis of 861
Mamainse,
Keweenawan rocks at,
described 172, 173, 756
red rocks intrusive at 229
referred to 67, 229, 755, 886
Mamainse conglomerates at 67
copper at 175
geological position of section at 172, 173
Mamainse felsites 755
Man-engine, working of 925
Mandan ophite .... 175–750 passim, especially 205, 206, 248, 409, 490, 491
Mandan section, described 200–224
Mandan (i. e. Medora) section (in drill holes),
referred to 170, 180, 181, 193, 195, 197, 198, 199, 202, 236, 246, 248, 249, 250, 252, 253, 254, 255, 267, 275
Manebach twins 632, 634, 654
Manitou Mining Co.,
lode 233, 234
section described 231–257
Mabb ophite, distribution of 34, 190, 225, 229, 460, 471, 472, 476, 477, 484, 496, 498, 499, 523, 524, 828
grain of 170
Manitou,
section referred to 177, 183, 184, 185, 187, 188, 189, 193, 199, 200, 201, 206, 208, 210, 213, 216, 217, 218, 219, 220, 222, 223, 245, 254, 273, 275, 419, 653, 729
Mansfeld, Germany, copper at 874
Marcou, John B., reference 933
Marcou, Jules, reference 933
Marquette, Father J., reference 890
Marquette, Houghton and Ontonagon R. R 917
Martin, Lawrence, reference 938
Marvine, A. R., reference 30, 32, 34, 35, 53, 55, 148, 257, 258, 261, 266, 435, 437, 464, 465, 657, 664, 721, 873
See Eagle River section.
Marvine's conglomerates .... No. 1
No. 3 .... 225, 474, 483, 498, 499, 527, 544, 564, 828
See Baltic and Lac la belle conglomerates.
No. 4 .... 454, 460, 467, 470, 495, 563, 598
No. 5 .... 432, 453, 459, 467, 495, 563, 580, 596
No. 6 .... 432, 453, 460, 466, 498, 509, 528, 557, 565, 569, 574, 577, 583, 587, 591, 594, 595
No. 7 .... 464, 465, 508, 528, 532, 613
No. 8 .... 310, 394, 395, 432, 450, 459, 463, 505, 507, 527, 528, 529, 557, 565, 569, 574, 576, 594, 617, 736, 749
kinds of 69
occurrence of 34
pebbles of .... 175–750 passim
pebbles, alteration of 62
See Mt. Bohemia, St. Louis and Winona conglomerate.
See also Wolverine.
No. 9 .... 527 558, 736
No. 10.

Marvine's conglomerates—Continued.
See also Wolverine. Page
No. 11 715
No. 12.
See also Kearsarge conglomerate.
No. 13 439
See also Calumet conglomerate.
No. 14 698
See also Houghton conglomerate.
No. 15 .... 435, 439, 574, 694
See also Allouez and Albany and Boston conglomerates.
No. 16 .... 262, 559
See also Pewabic West conglomerate.
No. 17 .... 488, 635
See also Hancock West conglomerate and Ashbed.
No. 18 661
No. 21 640
Mason, R. T., reference 546, 548, 559, 563
Mass copper 962
Mass lode, referred 576, 588, 593, 611
section at, described 588–604
Mass Mine, reference 900
section at 569, 588, 825, 946
water in 825
Mayflower lode 371, 375, 932, 947
Mayflower Mine 947
McFarlane, Thos., reference 53
McCargoe Cove 738
McCulloch's Mine 716
McNair, F. W., acknowledgment 98
reference 96, 804, 820, 859
specific gravity tests.
notes on samples used in 348-366
McNaughton, Jas., acknowledgment 15
Medora lode 233, 248, 265, 409, 490
See Mandan.
Melaphyrporphyr, usage of term 64
Melaphyre 541, 653, 670
alteration of 92
analyses of 111
definition of 27, 53, 62, 63
soda 110
Melaphyre, doleritic
occurrence (see Doleritic texture) .... 175–750 passim
usage of term 66
Melaphyre, pegmatitic, usage of term 66
Melaphyre porphyrite 110, 433
pumiceous 578
Melilite in slags 77
Menlo Park Mine 876
Mendota,
described 226–228
drill holes referred to 190
Mendota vein, occurrence of 201
Merchant's lode 576
Mesnard (epidote, jasper or sandstone) lode 31, 310, 400, 409, 431, 433, 436, 490, 552, 558, 565, 626, 691
correlation of 37
Mesnard, Father, reference 890
Metapoikilitic texture described 141
Meuche, A. H., acknowledgment 13, 488
Meuche, A. H., reference 573, 586, 587, 614, 621, 622, 887, 938
Meuche, Karl S., reference 621, 810
Meuche, Leon, reference 621
Mica, petrographic description of 127

Page
Michigan Agricultural College 771
Michigan Geological Survey 894
Cooperation with U. S. G. S 893
Michigan Mine,
dip at 610
section at 604–613
See also Minnesota Mine.
South or contact vein 611
referred to 590
Microfelsitic texture, described 140
Micropegmatite, usage of term 63
Middle (Copper Harbor) Conglomerate, position of 37
Mine water, see water 788
Mineral land, appraisal of 896
Mineral Range R. R 917
Mineralizers,
effect of 30, 134, 135, 145, 149, 151
laws of loss of 152–169
Mines,
cost of equipment 887
depth of 919
timbering of 911, 919
Minesota Mine 899
See Michigan Mine.
Mining methods 920, 923
Minong conglomerate 728
Minong porphyrite 57
described 714
referred to 755
Minong trap,
described 716
reference 391, 392, 549, 605, 606, 607, 630, 724, 729
Minnesota conglomerate,
correlation of 557, 565, 569, 574, 590, 593, 610, 611
Minnesotare, defined 73
Mississippi Valley, salt water in 776
Modialopsis at Limestone Mt 525
Mohawk Mine, water of 811, 812, 820
Mohawkite,
occurrence 23, 426, 813
paragenesis 868, 869
Monadnocks 525
Montana, Belt copper formation in 942
Montreal lode 194, 209, 231, 250, 251, 364, 493, 555
Monument Rock, occurrence of greenstone there 29
Monzonase, defined 72
Moraines 888
Mosaic texture, described 141
Mosler, Chr., reference 54
Mottles, like Castile soap . . . . . 206, 3[illegible]1, 303
See ophite, pockilitic texture.
Mottling, irregular or banded.
See ophitic texture.
Mt. Bohemia Conglomerate,
horizon of 33
Mt. Bohemia, gabbro aplite.
analyses 108
petrographic descriptions, ... 229
Mt. Bohemia oligoclase gabbro,
analyses of 109
Mt. Bohemia ophite, analyses of 109
Mt. Houghton felsite . . . . . 83, 106, 175–750 passim, especially 565
Mud rock, cement, etc 583, 598, 591, 595, 599, 602
See clasolite and amygdaloid conglomerate.

Page
Mügge, O., reference.......... 767
Munroe, H. S., reference.......... 933
Myers, Jesse, photography by.......... 134

N.

Nankervis, J. L., acknowledgment.......... 89
National Mine.......... 900
National sandstone, referred to..........557, 565, 573, 574, 590, 610
Natrolite, paragenesis of..........858, 859, 861, 862, 871
Navitic texture, usage of term.......... 137
Nebraska Conglomerate, see Caledonia.
Nests,
of olivine.......... 740
New Arcadian Mine.......... 947
New Baltic Mine.......... 947
New Brunswick Mine.......... 876
New Jersey Copper..........776, 874, 875, 944
New Zealand Copper Mine.......... 870
Newton Mine.......... 876
Niagara,
occurrence at Limestone Mountain..........22, 521
Nickel, occurrence of..........869, 874
Nipigon Bay, igneous rocks on.......... 940
Nonesuch formation.
color of.......... 67
composition of..........92, 118
described..........40, 92, 456
lack of development.......... 945
occurrence of..........39, 40, 614, 622, 623, 625, 627
Nonesuch Mine..........761, 837, 855
North Kearsarge Mine..........814, 815, 869
North Lake Mine.......... 570
North Star.
See Kearsarge.
North Tamarack, highest beaches at.......... 49
temperatures at.......... 762
water from.......... 810
Norwich Mine.
See Copper Crown.

O.

Oberstein, Germany, copper at.......... 883
Ogemaw,
See Ogima.
Ogibway Mine, reference..........314, 315, 855
Ogima Mine, reference..........567, 576, 588, 593, 611
Old Colony Mine,
drill holes referred to..........375, 402, 421, 445, 947
Old Colony Mine, section described.......... 371
Old Colony sandstone..........304, 375
Old Pewabic amygdaloid..........407, 435
Olivine..........732, 750
altered, described..........127, 368, 375, 378, 422, 461, 575, 595, 599, 600, 601, 616, 645, 654, 657, 699 and 175–750 passim
corrosion of.......... 122
fresh.......... 741
grain of.......... 615
paragenesis of.......... 860
petrographic description of.......... 122
Olivine, alteration products of.
Bastite.......... 657

Olivine, alteration products of—Continued: Page
Bowlingite 127, 645, 654, 657
Iddingsite 375, 381, 382, 386, 388, 395, 595, 645, 654, 736
Iron oxides 584, 631
Mica 417, 461, 705
Rubellan 461
Serpentine 378, 417, 457
Talc 634
Ontario Bureau of Mines, reference 756
Oneco Mine 947
Ontonagon River Valley,
beaches in 49, 948
outcrops of Keweenawan in 625
Opaque minerals, petrographic description of 124
Ophitic texture,
alternately fine and coarse 211, 235, 257, 383, 399, 403, 404, 450, 470, 575
use of term .... 30, 130, 133 175–750 passim, especially 247, 515
very minute 182, 450, 598
Ophite,
composition of 109, 110–114, 515, 516
occurrence and grain in .... 65, 175–750 passim
usage of term 54, 65, 132
See also greenstone.
Orthoceras at Limestone Mountain 525
Orthoclase, paragenesis of 858, 861, 862, 864
Osann, A., classification of rocks by 73, 77, 518
Osceola Mine,
temperature in 760
water in 841
Osceola amygdaloid or lode 182, 191, 213, 253, 269, 365, 411, 423, 431, 441, 705, 706, 804
Outer (Copper Harbor) Conglomerate, position of..37, 39, 174, 328, 456, 605, 623, 625, 627, 630
Overburden, noteworthy 505, 535, 564, 567, 569, 832, 924
See pp. 175–750 passim.
Overhand stoping in mining 911
Overstrom tables, use of 929
Ovitz, F. K., analyses by 516, 783
Owl Creek vein 260, 262

P.

Packard, R. L., analyses by 774
Palache, Charles, reference 861, 934
Palaeozoic strata at Limestone Mountain 22, 524
See also Jacobsville sandstone.
Palisade trap, comparison with 737, 875
Paragenesis 276–297, 373, 615, 858, 860, 861, 864, 879
See mineral names.
Parnall, W. E., reference 762
Pascoe, P. W., reference 786
Patton, H. B., reference 56, 91
Paull, J. F., reference 805
Paull, James 893
Pectolite 672, 849
Pegmatites, connection of doleritic texture with 66
Peirce, B. O., reference 763, 765, 769, 938
Peneplain,
Cretaceous 941
Pre-Cambrian 941
Penhallegon, W. J., acknowledgment 15, 29, 225, 233
Pentamerus at Limestone Mountain 525
Percussion table, use in mining 914
Permian, copper deposits of 874, 883
Permits, mining, issue by U. S. Government of 895
Peters, A. D., on diffusivity of snow 771
Peterson, J. O., reference 561, 563

Page
Petrographic descriptions 120-144, 639-755
Petrographic, description of.
apatite 128
augite 122, 382
calcite 126, 539
clay and kaolin 128
copper 127
datolite 127, 561
dolerite 721
epidote 127
feldspar 123, 480, 515, 655-755
fluorite 128
laumontite 125
mica 127
Olivine 122
opaque minerals 124
plagioclase 312, 313, 378, 383, 393, 457, 480, 515, 630-755
quartz 123
sandstone 544
steam sediment 416
sulphides 128
thomsonite 125
viridite 124
wollastonite 125
Pewabic amygdaloid lode 262, 407, 435, 488, 489, 491, 536, 550, 685, 686, 689, 797, 799, 805, 906
Pewabic West Conglomerate 243, 546, 550, 551, 680, 681
See Marvine's Conglomerate 16
Phelps, Frank B., reference 933
Phenocrysts . . . . 175-750 passim, especially 220, 678, 693
See rhyocrystals, brotocrystals, eocrysts, Kearsarge lode.
Phoenix Mine 897
geology at 311, 312
work in 897
Physiography,
of Lake Superior region 17, 21, 48-51, 486, 527, 564, 588, 604, 887, 888, 909, 940, 941
Pickford, water from well at 839
Pigeon Point, origin of rocks at 77, 82
Pirsson, L. V., reference 27
Piscatqua lode 567, 593
Pistazite 866
Pits, exploring 909
Pittsburg and Boston Mining Company 896
Placerose, defined 72
Plagioclase,
distribution and grain of . . . . 175-750 passim
petrographic description of 123, 312, 313, 515, 630-755
See also doleritic texture.
Plagioclasite, defined 71
Plagiophyre 321, 367
See Kearsarge lode and glomeroporphyrite.
Plate I., referred to 29, 629
Plate II., referred to 29, 69, 112, 133, 148, 245
Plate III., referred to 112, 133, 148, 190, 245, 247
Plate IV., referred to 30, 133, 134, 147, 148, 174
Plate V., referred to 30, 40, 67, 148
Plate VI., referred to 74, 133, 147, 148, 515
Plate VII., referred to 64, 65, 69, 134, 137, 138, 139, 148, 203, 224, 315, 418
Plate VIII, referred to 35, 622, 624, 946
Plate IX., error in, corrected 947
referred to 29, 315, 316, 328, 424, 427, 430, 456, 757, 850
Plate X., referred to 430, 458, 485, 486, 491, 493, 494, 498, 947
Plate XI., referred to 505, 527, 564

Page

Plate XII, referred to 527, 536, 546, 548, 564, 689
Plate XIII, referred to 564, 566, 574, 946
Plate XIV, referred to 574, 588, 604, 609, 611, 612, 946
Plate XV., referred to 614, 621, 622
Pleurotomaria at Limestone Mountain 525
Poikilitic texture 148, 631
See ophitic texture.
Poikilophitic texture, defined 132
See ophitic texture.
Point Houghton sandstone 40, 92, 118, 629
Pollard, J., acknowledgment 15, 859, 864
Pope, Graham, reference 762, 889, 905
Porcupine Mts 573, 622
Chippewa felsite of 560
felsite at 83
formations of 49, 941
gabbro 229, 624
Porcupine Mountains, highest beach at 49, 948
lake shore at 50
thickness of Nonesuch shales at 40, 622
thickness of Outer Conglomerate at 39, 623
Pore space, in amygdaloid 806
in conglomerate 809
in Marquette diabase 100
Porphyrite,
defined 72
occurrence .... 175–750 passim
See especially Minong trap, glomeroporphyrite, Ashbed group.
Porphyrite below Mt. Houghton quartz porphyry,
analyses of 107
Porphyritic crystals, definition of 27, 81
See Kearsarge lode.
See phenocrysts, brotocrystals, rhyocrystals, eocrystals
Porphyritic hiatal texture, definition of term 138
distribution .... 175–750 passim
See especially Greenstone, Kearsarge Lode, Huginnin porphyrite.
Porphyry,
occurrence of .... especially, 263, 400, 624, 636
See also felsite.
usage of term 33, 52, 58, 59, 60
Porphyry tuff 691, 753
See also Mesnard lode.
Portage Lake.
faulting near 486, 487, 491
thickness of Central Group 35
Portage Lake Smelting works 916
Portage Mining Co 905
Portage River Improvement Co 906
Potassium,
in alterations 94
in rock analyses 99–119
water analyses 781–841
Powder House vein and ophite 573, 590, 609, 612
Powellite, paragenesis of 859, 860
Praysville porphyry 263
Precht, J. reference 862
Prehistoric mining 488, 890
Prehnite 849, 876
analyses of 93, 104
occurrence .... 42, 93, 94, 104, 175–750 passim,—
especially 375, 376, 377, 513, 571, 662, 681, 685, 726, 847
paragenesis of 94, 615, 858, 860
pink copper bearing 222, 239, 302, 303, 305, 308,
397, 462, 468, 482, 616, 617, 619

Prehnite—Continued. Page
with copper....214, 234, 252, 266, 291, 298, 424, 425, 447, 587, 600, 607, 616, 639, 684, 687, 700, 705, 706, 711, 722, 723, 724, 733, 735, 738, 831
Presque Isle River, section.... 625
Propagation, of hot and cold waves.
See diffusivity.
Pryor, Reg. C., acknowledgment....15, 431, 432
reference....437, 440, 442, 443, 444, 447, 449
Pyroxene.
See augite.
Pyrrhotite.
paragenesis of.... 861
Puca sandstone, copper in.... 879
Pumniceous amygdaloid conglomerate....69, 401–403, 406, 578, 581, 585, 620, 694
Pumpelly, Raphael, reference....29, 41, 45, 53, 54,87, 94, 111, 265, 267, 774, 868

Q.

Quarry moisture.... 806
Quartz,
crystals....279, 767, 860
occurrence of....552, 607, 639, 685, 687
paragenesis of....858, 860, 864
petrographic description of.... 123
Quantitative classification.
described.... 71
referred to....58, 516
Quartz porphyry.... 400
Mt. Houghton, analyses of.... 106
See porphyry and felsite.
Quaternary.
See overburden and glacial phenomena.
Queneau, A. L., reference.... 157
Quincy Mine, geology at....224, 431, 435, 487, 491, 791, 793, 799, 868, 910
mining methods in....905, 910
samples from.
temperatures in....760, 762
waters in....760, 790–796

R.

Rafinesquina at Limestone Mountain.... 525
Ragged amydgdaloid....410, 490
Ramos at Corocoro.... 880
Randville dolomite....780, 781
Ravines showing faults.... 22
Raymond, Mr., reference.... 896
Red Beds.... 941
Red rock, defined.... 59
Reeder, J. T., reference.... 857
Republic Mine.... 786
Rhode Island drill hole, described....424–429
Rhode Island drill holes referred to....325, 326, 869
Rhyocrystals....80, 244, 246, 247, 379
Rhyolite.... 55
Richards, Jas. E., acknowledgment.... 15
Rickard, T. A., reference....799, 935
Ridge Mine.... 900
Ridley, F. W. acknowledgment.... 15
Rivot, M. L. E., reference.... 52
Roberts, J. F.... 761
Rockland Creek.... 606
Rockland, geology near....40, 565, 573, 574, 610
Rockland sandstone.
See National Sandstone.

Page
Rockland vein 573, 610
Rocky Hill (Griggstown, N. J.) Mine 875
Rolling Mills 917
Rominger, C., reference 54, 257, 593, 624
Rose, R. S., reference 935
Rosenbusch, H., reference 53, 54, 57, 59
Roughing jigs 929
Rubellan, see Olivine, alteration products of.
Ruthven, A. G., reference 936

S.

Salt crystals, paragenesis of 859
St. Croix sandstone 630
St. John's Creek, sandstone on 487
St. Louis conglomerate 33, 400, 932
See Bohemia Conglomerate.
St. Louis property, geology on 365, 371
St. Mary's epidote
See Mesnard lode.
St. Mary's Mineral Land Co. (Challenge exploration) 506, 833, 906
Salfemone, defined 72, 518
Sandstone (generally red or chocolate) 175-750 passim,—especially 680, 753, 601
See sediment and mudrock.
analyses of 629
basic 519, 578, 581
blanched red 880
epidotic or green 235, 275, 301, 369, 370, 386, 426, 445, 451, 510, 520, 542, 577
indurated 510, 520, 535, 536, 564
Wolverine, Marvine's No. 9 . . . . 369, 370
Santorin 885
Saponite, paragenesis of 860
Savicki, W. V., reference 371, 624, 606, 621, 935
Sawyer, A. H., acknowledgment 15
Schneider, C. F., reference 757
Schultz, A. R., reference 841
Schultz, R. S., acknowledgment 15
reference 614
Schoolcraft, H. R., reference 892
Scoriaceous conglomerate, defined 31, 69
Scotland, copper in Old Red Sandstone of 874
Scott, D. D., acknowledgment 15
Scovill Point 692
Seaman, A. E., reference 860, 941, 947
Sediment . . . . 115, 175-750 passim,—especially 703
analyses of
coating in amydgaloid 641
composition of 91–93
concentration of
elements in 91
contact effects on (epidotized sandstone) 228, 238, 239, 255
copper bearing 237, 431, 445
amount in Central group 34
occurrence between Kearsarge and Wolverine 256, 273, 298
per cent of 34, 455
See conglomerate, sandstone, clasolite.
Seeber, R. R. acknowledgment 15
reference 505
Selenite, paragenesis of 858
See gypsum.
Separk, E. A., reference 782
Seriate porphyritic texture 138, 723
See also glomeroporhyritic.

Serpentine, see Olivine, alteration products of Page
paragenesis of....858, 860
Shaft pillars....921
Shafts of mines....910
Shale, red....640
See sediment and mud
Shattered zone....828
See Shear zone and Breccia.
Shawmut conglomerate....527, 536, 546, 554
Shear zones....25, 47, 475, 476, 513, 535, 539, 583, 828
Shelden amygdaloid....448
Sheldon, C. D., reference....761, 905
Shields, E., acknowledgment....432
Shields, R. H., acknowledgment....15, 432
Shoots, described....47
occurrence of....610, 808, 810, 850
Shumway, F. W., reference....837
Siderite,
occurrence of....389
paragenesis of....860
See ankerite.
Siebenthal, W. A....786
Sienite (Syenite)....52
See gabbro aplite.
Silica
in alterations....94
in rock analyses....99–119
water analyses....781–841
Silver mountain, exposure of Keweenawan rocks at....18, 625
Silver Islet Mine, saltwater and gas at....774, 788
Silver, occurrence of....43, 262, 616, 931
paragenesis of....860, 861, 863
Siskowit Point....92, 651, 692
See Point Houghton.
Skips....902, 913, 923
size of....912
Slaughter, W. F....786
Slicken-siding,
defined....25
occurrence of....175–750 passim,—especially 268, 294, 363
Slides,
defined....25
in Central Mine....264
occurrence of....175–750 passim,—especially 261, 263, 539, 543, 555, 560
Slime table, use of....914
Slip, see Shear zone.
Smillie, S., reference....760, 762, 790, 791
Smith, Fred, acknowledgment....15
Smith, P. S., reference....260, 263, 271, 276, 371, 606, 624
Smyth, H. L., reference....783, 807, 808
Snow,
Propagation of hot and cold waves into....771
Sodium,
in alterations....94, 777
in melaphyres....82, 110
See glomeroporphyritic.
in rock analyses....99–119
in water analyses....781–841
Somerville (American) Mine,
origin of copper in....876, 944
South Brother Hill, near Rockland....612
South Hecla part of Calumet Mine, salt and powellite in....859
South Kearsarge branch of Osceola Mine....820, 844, 919
South Lake Mining Co....566, 570, 574, 946

South Quincy
 See Dacotah Heights. Page
South Range ... 625
South Range Mining Company, drill holes ... 493
Specific gravity ... 96–99
 changes affecting ... 765
 of rocks ... 96–99, 920, 947
 of water ... 519, 777, 779, 797–799, 814–818, 826, 949
Spherulitic texture ... 140, 754
Stamps ... 914, 929
 cost of ... 931
 water used by ... 931
Stamp mill ... 912, 927, 930
Stamp rock ... 888, 902
Steidtmann, Edward, reference ... 938
Steiger, G., reference ... 790
Steinmann, G, reference ... 874, 880, 881, 884, 936
Stevens, H. J., reference ... 871, 936, 938
Stilbite, occurrence of ... 303
Stockly, W. W., acknowledgment ... 15, 263
 reference ... 260, 374, 391, 392, 400, 486, 689, 716, 774, 849
Stockwerk.
 See Shear zones.
Stokes, H. N ... 757, 766, 847, 848
Stonington ... 525
 Geology near
Strikes abnormal ... 566
 (See faults)
Stromboli, copper in exhalations of ... 885
Strontium, occurrence of ... 803
Sulitelma type, of rock ... 518
Sullivan, E. C., reference ... 850
Sulphide.
 description of, petrographic ... 128
 occurrence only near intrusives ... 228, 756, 942
Sulphur ... 830
 in copper ... 869, 871
 in water ... 835–837
 role of, in copper formation ... 944
Summit mining property ... 259
Sundt, L., reference ... 880
Superfusion, effect of ... 146, 165
Superior shafts ... 829
Superior and Ottawa Mine, Wisconsin ... 783
Swedetown Creek, geological section on ... 456
Sweet, E. T., reference ... 92

T.

Tailings, copper in ... 916
Tamarack cross-section, notes on 30th level ... 337–348
Tamarack Junior Mine, water and conglomerate in ... 803
Tamarack Mine ... 656
 geological section in ... 333–365
 references to ... 142, 408, 434, 435, 548, 652, 656, 662, 691
 sinking, timbering, etc. in ... 918–924
 temperature in ... 760, 762
 water in ... 802–806, 808–810
Tammann, G., reference ... 139, 149, 150, 675
Tarr, W. A., reference ... 937
Taylor, F. B., reference ... 933, 934
Tecumseh shafts of La Salle property,
 salt water at ... 821, 844
 section ... 327, 374
Tehamose, defined ... 71

Page
Tellurium, characteristic of Western copper 863
Temperature,
causes of low 764, 770
effect of ice age on 763, 767, 768
of downward working waters 766
explanation of 763
increase of 768
Temperatures
of air 757, 758
of mines 758, 759, 760, 761, 762, 786, 797
of soils 757, 760
of water 759, 761, 780, 840, 949
Texture,
petrographic 27, 128–141
variation of, near amygdule 711
Thallite (epidote) 866
Thermal waters, see waters hot
Third Brother hill, geology of 612
Thomas shaft, of Arnold Mine 261, 262
Thomsonite . . . . . 175–750 passim, —especially 376, 949
occurrence of 208
paragenesis of 858, 861
petrographic description of 125
Thunder Bay, dolomites and dolomitic marls at 67
Thwaites, F. T., reference 628, 938, 940
Tight, W. G., reference 55
Tobin porphyrite, defined 56, 65
referred to 431, 661, 700
Todd Harbor 714
Toledo claimed by Michigan 892
Toltec Mine 574
Tonalose Dacose, defined 72
Torch Lake Mining Company,
geological section of 374, 404
referred to 422, 486, 524, 620, 715, 729
Tourmaline, occurrence at Champion Iron Mine 788
Town 44 North, Range 34 W 505
T. 46 N., R. 2 E. (Wisconsin 628
T. 46 N., R. 41 W 628
T. 47 N., R. 46 W 628, 784
T. 47 N., R. 47 W 628
T. 48 N., R. 37 W 629
T. 49 N., R. 35 W 629
T. 49 N., R. 36 W 629
T. 49 N., R. 40 W 621
T. 49 N., R. 41 W 622
T. 49 N., R. 42 W 624
T. 50 N., R. 30 W 243, 246
T. 50 N., R. 33 W 402
T. 50 N., R. 38 W 865
T. 50 N., R. 39 W 588
T. 50 N., R. 39 W 565, 604, 610
T. 50 N., R. 44 W 624
T. 51 N., R. 33 W 380
T. 51 N., R. 35 W 22, 524, 525
T. 51 N., R. 37 W 564, 565, 567, 569, 570
T. 51 N., R. 38 W 573, 574, 586, 589, 591
T. 51 N., R. 42 W 624
T. 52 N., R. 35 W 506, 531
T. 52 N., R. 36 W 531, 532, 534, 535, 536, 538, 539, 540, 541, 542, 543, 544, 545, 548, 549
T. 52 N., R. 37 W 548
T. 53 N., R. 35 W 515
T. 54 N., R. 34 W 479, 481, 491, 492, 494
T. 55 N., R. 33 W 406, 419, 424, 427, 429, 430

Page
T. 55 N., R. 34 W..........40, 143
T. 55 N., R. 35 W..........505, 508, 514
T. 56 N., R. 31 W.......... 229
T. 56 N., R. 32 W..........33, 365, 373, 400, 919
T. 56 N., R. 33 W..........25, 319, 327, 367, 374, 375, 376, 382, 383
T. 56 N., R. 33 W..........387, 391, 394, 400, 404, 919
T. 57 N., R. 27 W.......... 174
T. 57 N., R. 31 W..........229, 314
T. 57 N., R. 32 W..........25, 33, 128, 315
T. 57 N., R. 33 W.......... 328
T. 58 N., R. 28 W..........142, 175, 176, 178, 179, 189, 192, 755
T. 58 N., R. 29 W..........200, 226, 229, 231, 459
T. 58 N., R. 30 W..........205, 250, 252, 259, 459
T. 58 N., R. 31 W..........263, 270, 272
T. 58 N., R. 31 W..........35, 142
T. 58 N., R. 32 W.......... 142
T. 58 N., R. 37 W.......... 142
T. 58 N., R. 38 W.......... 172
T. 64 N., R. 37 W.......... 651
T. 65 N., R. 36 W.......... 651
T. 66 N., R. 35 W.......... 738
Trap, definition of..........27, 51, 64
Trachyte.......... 55
Trap rock, composition of.......... 26
Tretheway, M., reference..........267, 271, 829
Triassic..........883, 885, 936
Copper of New Jersey.
Trichites (marginal) texture..........175–750 passim,—especially 643, 696, 700, 726
Trimountain Mine,
methods in..........918, 922
salt water in..........830, 831
Trochonema, at Limestone Mt.......... 525
Troctolite, facies like.......... 750
Tufaceous texture, described.......... 141
See also amygdaloid conglomerate and pages..........175–750 passim
Tuff, defined.......... 59

U.

U. S. Geological Survey Bulletin.......... 418
analyses from.......... 103
Umptekase, defined.......... 72
Umptekose, defined.......... 72
Union Springs, water of.......... 841
Upper Peninsula, history of.......... 892
Uren, W. J., acknowledgment.......... 15
references..........532, 857
Urinometer, use in water testing..........778, 786, 805

V.

Vaalose, defined.......... 72
Van Hise, C. R., reference..........13, 91, 775, 852, 933, 934, 938. 941, 943
Van Orden, F., reference..........536, 537, 540, 544
Van't Hoff, J. H., reference.......... 844
Varioloid greenstone, occurrence of.......... 29
Vetas, at Corocoro copper mine.......... 880
Victoria lode.......... 616
Victoria Mine geological section..........576, 578, 579, 614, 825, 855, 856
Viridite, petrographic description of.......... 124
Viscosity, effect of.......... 129
Vitrophyric texture, described.......... 140
Vivian, Johnson, reference..........774, 789, 849, 861
Vogt, J. H. L., reference..........79, 155

Volcanic focus, Page
at Mt. Bohemia 627
at Porcupines 624, 625, 627
Vulcan Mine,
waters of 780, 781

W.

Walcott, C. D., reference 940
Wall ravine, occurrence of 22
Ware, E. E., analyses by 99, 781
Washington harbor 707
Washington Island 678, 692
Washington River 707
Water,
alteration by 45–47, 87–96, 399
analyses of 522, 523, 570
corrosive effect of 808
effect on crystallization 28
(See doleritic and granophyric texture)
hot, effect of 42, 83, 84, 140
See mineralizers.
magmatic
circulation of 884, 885
migration of 857
of mine 372, 409, 774, 775, 778, 780, 809
analyses of 780, 785, 787–846, 948
amount of 780, 786, 787
character of 928
concentration of 834, 856
contraction of, in cooling 854
importance in copper deposition 44
middle 846
origin of 43, 845, 846, 942, 943
salty 43, 271, 522, 614, 618, 784, 787
of ocean 777
of surface 837
Waterbury and Detroit Copper Co 916
Waterbury Mining property 259
Weed, W. H., reference 936
Weidman, S., reference 841
Wendigo property 716
Wheal Kate 505, 904
altitude 49
Wheeler, H. A., reference 760, 763, 764
White, C. P., reference 155
White Pine Mine 623
Whitneyite, paragenesis of 831, 861, 868
Wichmann, C. A., reference 53
Wifley table 914, 929
Wilcox, J. M., acknowledgment to 15
Wilson, F. B., reference 804, 816, 834
Wearne, W., reference 569, 843
Wilson, J. G., reference 940
Winchell, A 52
Winchell, A. N.,
analyses by 100, 103
reference 27, 51, 58, 71, 81, 120, 122, 654, 660, 670, 937, 938, 949
on ophitic texture 130–132
Winchell, H. V., reference 813, 869
Winchell, N. H., reference 58, 122
Winona conglomerate 547, 563, 566
See Marvines conglomerate 8
Winona drill holes, described 549–564
referred to 461, 507, 537, 538, 544

Page
Winona lode . . . 524, 536, 558, 564
dip of . . . 547
hanging of . . . 530
Winona Mine . . . 546, 561, 824, 837
trench I . . . 561
J . . . 561
K . . . 561
Winzes, use in mining . . . 910
Wollastonite, petrographic description of . . . 125
Wolverine Mine,
geology of described . . . 317–318
reference to . . . 413, 414
salt water in . . . 816–818
shafts of . . . 926
Wolverine sandstone . . . 35, 218–750 passim,—especially 218, 257, 274, 428, 443, 556, 626, 721, 727
character of beds near . . . 298, 431
occurrence of . . . 183–750 passim,—especially 558
reduction by slide . . . 26
See also Marvine's conglomerate, 9.
Wood, A. B., acknowledgment . . . 464
Woodward, R. S., reference . . . 158, 932
Wright, C. A., acknowledgment . . . 15
Wright, F. E., reference . . . 57, 59, 108, 122, 153, 201, 225, 229, 767, 935, 936
Wright, J. N., reference . . . 934
Wright Island . . . 630
"Wyoming" property . . . 192
Wyandotte drill holes, described . . . 536–545
Wyandotte Mining Co. . . . 536
referred to . . . 507, 531

Y.

Yale Mine . . . 784

Z.

Zonar extinctions . . . 724
Zeolites,
in amygdules . . . 175–750 passim,—especially 654
paragenesis of . . . 42, 43, 97, 672, 681, 685, 696, 765, 811, 944
See prehnite, apophyllite, analcite, thomsonite, chlorastrolite.

W